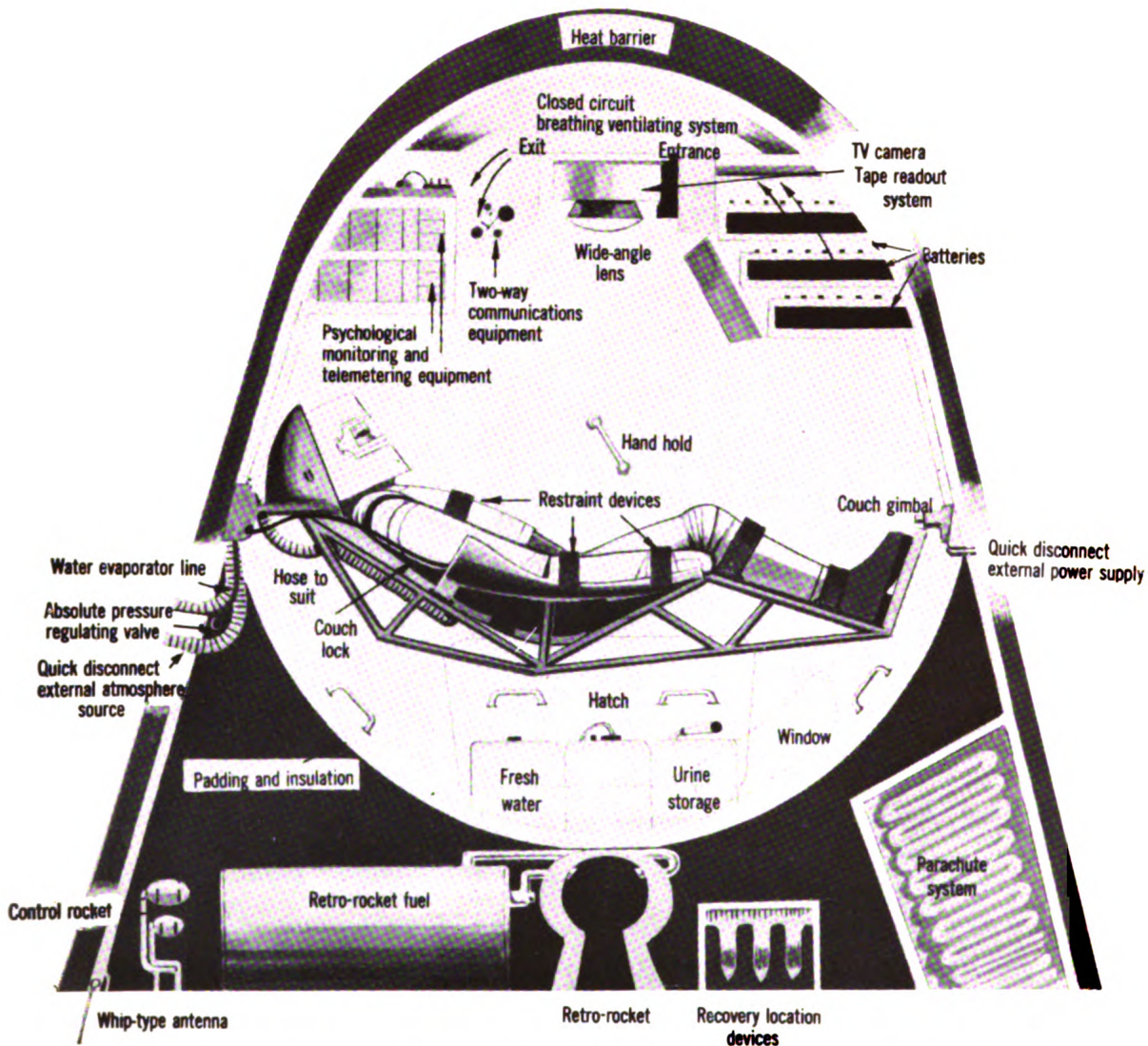


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PRINCIPLES OF GUIDED MISSILE DESIGN



INTERIOR OF A MANNED ORBITAL VEHICLE. This cutaway drawing shows an artist's conception how a U.S. Air Force passenger might look aboard one of the first manned orbital vehicles to be sent into space. Every foreseeable comfort and device would be built into the container to allow maximum reliability for both man and machine. The spaceman reclines on a padded couch to protect him from increased G forces. His physiological reactions—heart action, temperature, rate of breathing, and the like—are telemetered to earth, and he breathes a closed-circuit atmosphere and wears protective body gear. (*U.S. Air Force Photograph*)

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PREFACE

The "Dictionary of Guided Missiles and Space Flight" is the fifth volume in the series PRINCIPLES OF GUIDED MISSILE DESIGN. Other titles in the series are "Guidance"; "Aerodynamics, Propulsion, Structures and Design Practice"; "Operations Research, Armament, Launching"; "Missile Engineering Handbook"; "Space Flight I—Environment and Celestial Mechanics"; "Space Flight II—Dynamics"; "Space Flight III—Operations"; "Systems Preliminary Design"; "Airborne Radar"; "Range Testing"; and "Automatic Flight Control."

Guided missiles and space flight encompass a human endeavor which is unsurpassed in technical complexity and dependence upon effective communication between the workers in the field. It is the purpose of this book to facilitate the establishment of a common language in the selected field by offering a compendium of commonly used terms, defining these and providing discursive statements to enable better visualization of their usage.

The terms defined comprise the names of guided missiles and spacecraft; the various guidance and control, propulsion armament, and launching systems of which they are formed; the components that make up those systems; and all related terms from aerodynamics, astrodynamics, electronics, astronomy and physics. The latter include terms covering antennas, circuits, radars, rockets and propellants, as well as the important laws, relationships, equations and concepts which govern their utilization and design.

In view of its character both as a dictionary and an encyclopedia, this book can be used as a source of exact definitions and of more detailed explanations. It will be of interest to all those working in the field, including both military and civilian personnel concerned with research, design or operation of guided missiles and spacecraft. Illustrations and discussions have been supplied where better understanding of important terms will result.

To facilitate the use of the book as a reference, a plan of cross-referencing has been devised. Wherever in the definition of a given term other words or expressions are used for which cross-reference is available, those words or expressions are printed in bold-face type, so that the reader need only turn to the corresponding entry to find additional information. Terms having multiple definitions are supplied with these under different numbers.

Obviously, the objective of this book is ambitious, and necessarily calls for compromises. The editor's idea of what terms are commonly used and therefore worthy of inclusion will doubtless fall short in the judgment of many readers. There will be serious omissions and the rigorosity of

definition and usage will be questioned. One can only say that this book is the product of experienced men who are conscious of their limitations but believe implicitly in the importance of the book's objective. It is hoped that criticisms can be translated into a continuously improved Dictionary.

This book is intended to be a desk-side companion of the "International Dictionary of Physics and Electronics" as well as the fifth volume of the series **PRINCIPLES OF GUIDED MISSILE DESIGN**, all by the same publisher. Thus it will be found that its many entries represent, directly or indirectly, the work of such men as W.C. Michels, C.W. Besserer, H. Goldberg, and K.A. Ehricke. Special acknowledgment is due Major B.B. Small, USA, who contributed original material. Some of the terms are from the "Aeronautical Dictionary," by Dr. Frank Adams of the National Aeronautics and Space Administration. Documents prepared by several other elements of the Department of Defense, and many U.S. professional societies have also been culled for this work.

The editor, speaking for the many who have worked on this book, hopes that it will be an instrument for advancing guided missile and space flight work in the English-speaking nations, especially if this work is directed increasingly toward the betterment of man rather than his destruction.

GRAYSON MERRILL

A

A. (1) Linear acceleration (a). (2) Mean sound absorption coefficient (a). (3) Element argon (A). (4) Angstrom unit (A or Å). (5) Ampere (a). (6) Velocity of sound (a). (7) Critical velocity of sound (a^*). (8) Cross-sectional area of flow channel through a solid propellant (A_p). (9) Cross-sectional area at throat of a rocket (A_t). (10) Accommodation coefficient (a). (11) Amplitude (A). (12) Refracting angle of prism (A). (13) Area (A). (14) Specific rotation of light $[\alpha]$. (15) Free energy, Helmholtz, which is also known as isothermal work function, total (A), per unit mass (a), per mole (a , A or A_m). (16) Atomic weight (A). (17) Magnetic vector potential (A).

A-1, A-2 . . . A-10. A series of German research rockets developed by the *Heeres Waffenanst* during the program of development which produced the V-2 rocket missile used late in World War II.

AAM. Air-to-air missile. (See **missile, air-to-air; missile, guided; model designation.**)

AAM-N-2 . . . AAM-N-4. A series of U.S. Navy missiles. The #2 was the Sperry **Sparrow**, #3, the Douglas Sparrow and #4, the Raytheon Sparrow. The corresponding code names are: "Sparrow 1, Sparrow 2 and Sparrow 3."

AAM-N-7. U.S. Navy air-to-air missile; the Philco or GF **Sidewinder**.

A BATTERY. Power source for filaments in battery-operated electronic equipment. (See also **A Supply.**)

A SUPPLY. The source of the heating current for the cathode of an electronic tube. In the early days of radio the various voltages needed to operate a receiver were obtained from batteries, called A, B and C batteries, supplying the filament, plate and grid voltages respectively. These letter designations have

carried over to the present-day sources, although the voltages are usually obtained now from an a-c source, either directly as in the case of the A supply or indirectly for B and C voltages.

AB PACK. A combined package of A and B power supplies for electronic equipment.

ABAMPERE. The cgs electromagnetic unit of electrical current. It is that current which, when flowing in straight parallel wires, 1 cm apart in free space, will produce a force of 2 dynes per cm length on each wire. (See **units and dimensions.**)

ABERRATION OF LIGHT. The apparent displacement of a star or other astronomical body, due to the motion of the earth in its orbit. For those stars at right angles to the direction of the earth's travel, the maximum effect is 20.5 seconds of arc, when the star is viewed normal to the velocity of the earth.

ABERRATION, OPTICAL. The failure of an optical system to form an image of a point as a point, of a straight line as a straight line, and of an angle as an equal angle. (See **chromatic aberration; spherical aberration; astigmatism; coma; curvature of field; distortion of the image.**)

ABL. Allegheny Ballistics Laboratory; Cumberland, Maryland.

ABLATION. The wearing away of surface material due to the action of a fluid moving past it at high speed and/or high temperature. This effect is used to advantage in one method of cooling of high speed bodies, such as long range **missile** nose cones or recoverable **satellite** vehicles. In this method the surface of the nose cone is composed of fusible material which is melted by the frictional heat of the ambient fluid. The melted material is continuously removed from the surface by ablation, thus carrying away the frictional heat, which otherwise would overheat the missile.

ABLE. A long-range, anti-submarine rocket with large amounts of conventional high explosives, which has been in service in the U.S. Navy for several years. (See illustration facing Page 26.)

ABLE. See **Thor-Able I.**

ABMA. Army Ballistics Missile Agency.

ABORTION. In missile operations: (1) A kill which prevents enemy targets from proceeding with their tactical missions. (2) An unplanned termination of a mission, usually excluding terminations caused by enemy action.

ABSCISSA. The horizontal co-ordinate of a point in a two-dimensional system, commonly rectangular Cartesian, and usually designated by *x*. Together with the **ordinate**, it locates the position of a point in a plane.

ABSOLUTE ANGLE OF ATTACK. The angle of attack measured from the position of zero lift for the **airfoil** in question.

ABSOLUTE CEILING. The maximum altitude above sea level at which a given airplane or airborne missile can maintain horizontal flight in a standard atmosphere.

ABSOLUTE HUMIDITY. The mass of water vapor in a specified volume. It can be expressed in any convenient units: ounces per cu. yd.; grams per cu. meter. Example: 22 grams per cu. meter.

ABSOLUTE PRESSURE. True pressure. The term *absolute pressure* is often used to distinguish from *gauge pressure*, which is the pressure above the pressure of the atmosphere. Instruments reading in gauge pressure have their zero at atmospheric pressure, so that to obtain the true or absolute pressure from the gauge reading, the pressure of the atmosphere must be added.

ABSOLUTE TEMPERATURE. The temperature measured from absolute zero, which is (-273.16°C) or (-459.69°F). (See **temperature scales**.)

ABSOLUTE UNITS. Any set of units defined in terms of fundamental (arbitrary) units of length, mass and time by connecting physical equations. (See **units and dimensions**.)

ABSOLUTE VELOCITY. Velocity, absolute.

ABSOLUTE ZERO. The temperature at which a system would undergo a reversible **isothermal** process without transfer of heat. This is the temperature at which the volume of an ideal gas would become zero. The value calculated from the limiting value of the coefficient of expansion of various real gases is -273.16°C . (0°K .) (459.69°F .) (0°R .)

ABSORPTION. (1) The process whereby the total number of particles emerging from a body is reduced relative to the number entering, as a result of interaction of the particles with the body. (2) The process whereby the kinetic energy of a particle is reduced while traversing a body. This loss of kinetic energy (of corpuscular radiation) is also referred to as **moderation**, slowing or stopping. (3) The process whereby some or all of the energy of **electromagnetic radiation** is transferred to the body on which it is incident or which it traverses. (4) The process of "attraction into the mass" of one substance by another, whereby the latter disappears.

ABSORPTION COEFFICIENT. (1) As applied to electromagnetic radiation and atomic and sub-atomic particles, the absorption coefficient is a measure of the rate of decrease in intensity of a beam of **photons** or **particles** in its passage through a particular substance. Since some of the loss of energy or particles is due to **scattering** or **reflection**, and some to true absorption, it is desirable to use the **extinction coefficient** to designate the total loss, and to restrict the absorption coefficient only to the second type of loss designated above. (2) As applied to **sound**, the absorption coefficient (which is also called *acoustical absorptivity*) is defined as the fraction of the incident sound energy absorbed by a surface or medium, the surface being considered part of an infinite area. (3) For the absorption of one substance or phase in another, as in the case of the absorption of a gas in a liquid, the absorption coefficient is the volume of gas dissolved by a specified volume of liquid.

ABSORPTION, RADAR. At frequencies above 15,000 megacycles per second, absorption becomes serious, affecting the range of radars to a degree that makes it prohibitively expensive in power to transmit microwaves over long distances. Fog can also produce

serious attenuation (absorption) if it is dense enough to reduce visibility to distances of 100 yards or less.

ABVOLT. The cgs electromagnetic unit of potential difference and electromotive force. It is the steady potential difference which must exist between two points in order that one erg of work be done when abcoulomb of charge is moved from one point to the other. (See **units and dimensions.**)

Ac. Actinium.

A-C-D-C RECEIVERS. Radio receivers designed without transformers in the power supply so that they may be connected either to alternating-current or direct-current sources. The heaters or filaments of the various tubes are connected in series with the proper series or parallel resistors to adjust the current to the correct value. A simple half-way type is shown.

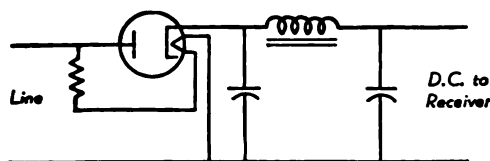


Plate supply of a-c d-c receiver.

ACCELERATION. The time rate of change of velocity. Like velocity, acceleration is a vector quantity, requiring the specification of both magnitude and direction, as well as sense. The defining equation is

$$a = \frac{dv}{dt}$$

where v is the instantaneous velocity and t is the time.

ACCELERATION, AMPLITUDE. Amplitude acceleration.

ACCELERATION, ANGULAR. The time rate of change of the angular velocity, expressed by the equation $d\omega/dt$ where ω is the instantaneous angular velocity and t is the time.

ACCELERATION, AVERAGE. If the instantaneous velocity of a particle is v_1 at a given instant and v_2 at a time Δt later, the average acceleration during the time Δt is defined as:

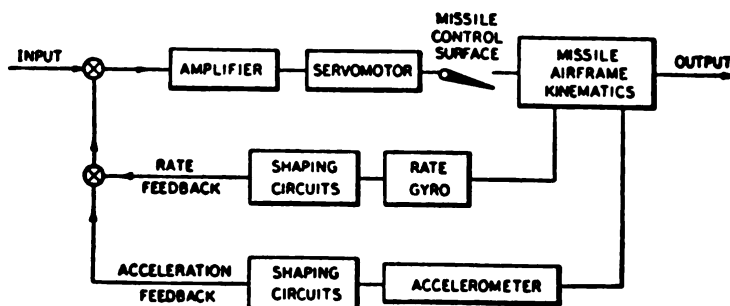
$$a_{av} = \frac{v_2 - v_1}{\Delta t}$$

ACCELERATION, AXIAL. Acceleration in the direction of a longitudinal axis, as of an airframe, air vehicle or space ship.

ACCELERATION BLOWOUT. The loss of combustion efficiency in a turbojet engine incident to an attempted acceleration and over-rich fuel mixture. The term does not normally apply to engines using an acceleration control. Synonymous expressions are *rich extinction* and *flameout*.

ACCELERATION ERROR. An error in a bubble sextant or magnetic compass reading caused by mechanical inertia during changes in velocity of the vehicle.

ACCELERATION FEEDBACK. A sensing system for control of a missile. In its operation, properly located **accelerometers** are used to sense body accelerations which are fed into the control system for correction of the motion. The method is commonly used to eliminate the effects of body bending, or to maintain **angles of attack** at predetermined values. (See figure.)



Simplified block diagram of autopilot, showing acceleration feedback.

ACCELERATION, LATERAL. Acceleration perpendicular to a longitudinal axis, as of an airframe, air vehicle or space ship.

ACCELERATION OF GRAVITY. (1) The ratio of the weight of a material particle to its mass at any specific point in an approximately uniform gravitational field. This is the acceleration with which a body would fall in the absence of all other disturbing forces, such as those due to friction. (2) Specifically, the acceleration with which a body falls *in vacuo* at a given point on or near a given point on the earth's surface. This acceleration, frequently denoted by g , varies by less than one percent over the entire surface of the earth. Its "average value" has been defined by the International Commission of Weights and Measures as 9.80665 meters per second per second or 32.174 feet per second per second. Its value at the poles is 9.8321 meters per second per second, and at the equator is 9.7799 meters per second per second.

ACCELERATION, PHANTOM. Phantom Acceleration.

ACCELERATION SPECTRAL DENSITY (POWER SPECTRAL DENSITY). A measure of the energy distribution in a complex wave. It is expressed by the following relationships:

$$PSD = g^2 / \Delta F,$$

and

$$g = \sqrt{\frac{1}{2} \Sigma A},$$

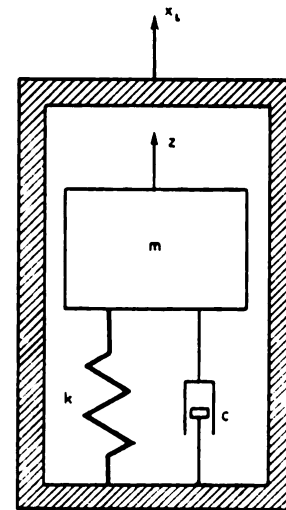
where PSD is the intensity for one cycle of band width, ΔF is the band width in cycles per second, g is the root-mean-square value of the acceleration, and A is the maximum amplitude of acceleration for each frequency in the band width.

ACCELERATION TOLERANCE. The tolerance of acceleration forces by personnel or equipment.

ACCELERATOR, LINEAR. Linear accelerometer.

ACCELEROMETER. An instrument for determining acceleration of a system with which it moves. The simplest types consist of a spring-suspended mass which is set back by the vehicle's acceleration against a calibrated spring tension. (See figure.) More sensitive types are based upon the principle of

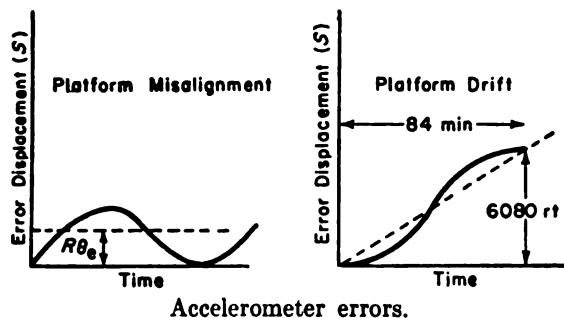
the **gyroscope**, the latter being caused to precess by an unbalanced force developed on some sensitive axis of rotation. Another type is the manometer accelerometer, consisting of twin glass tubes containing an electrolytic solution. The acceleration causes a movement of the electrolyte, which is recorded by means of a Wheatstone bridge circuit.



Linear accelerometer as single degree-of-freedom system.

ACCELEROMETER ERRORS. Four common sources of error recognized in use of the accelerometer. They are as follows: (1) *Accelerometer sensitivity.* To estimate the navigational displacement error due to the sensitivity of the accelerometer, the following formula is used: $S_e = \frac{1}{2} k g t^2$, where S_e is displacement error, k is the accelerometer's threshold sensitivity, g is acceleration of gravity, and t is time during which the error acts, (e.g., the time of flight). (2) *Misalignment of the reference platform.* Errors of this type have two components, as shown in the following mathematical expression: $S_e = -R\theta \cos \sqrt{g/Rt} + R\theta$, where S_e is the displacement error, g is the acceleration of gravity, R is the radius of the earth, t is the time of flight, and θ is the platform misalignment angle. In this formula the lateral error of the missile is taken to be the sum of a periodic error and a constant error. Since the period of this part of the equation is 84.3 minutes, this component is often called the "84-minute error." Moreover, the platform on which missile acceleration is based is commonly supervised by gyros, so that any drift of these gyros will

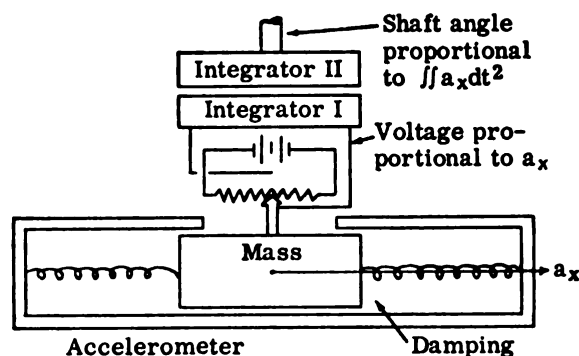
add another error to the guidance system so referenced. The missile error due to this drift is equal to its rate times the time of flight, and thus tends to increase linearly. Then, impressed upon this linear error there is a second component of the 84-minute oscillation.



Some guidance systems use two sets of redundant gyros, rotating one gyro at a time and later switching to the second, which meanwhile has been brought up to speed with rotation in the opposite direction. As each gyro is alternately rotated in the opposite direction, the platform drift and other random errors are theoretically canceled. Thus the primary cause of this 84-minute oscillation is the sum of the basic inaccuracies in the reference system. Once an error is obtained it will persist with the 84-minute period as long as the missile is within the gravitational influence of the earth. (3) *Earth reference errors.* An earth-fixed frame of reference does not correspond to a pure inertial system without corrections. This can be seen from the fact that the earth itself is moving, i.e., it is rotating on its axis; it is traveling about the sun; and in a larger frame of reference, it is moving with the solar system in its journey through the universe. However, the last of these errors may be disregarded if the missile is intended to journey from one point on the earth to another. The effect of the first two motions is to produce errors whose magnitudes are proportional to the velocity of the missile. It may be analyzed in terms of **centripetal acceleration** of the earth and the **Coriolis acceleration**. The centripetal acceleration will act whether the missile is stationary or moving, and is not usually separated from the gravitational attraction, with which it acts colinearly to produce the net acceleration of gravity. The Coriolis acceleration is completely proportional to the velocity of the body; when the

body is at rest, the Coriolis effect is zero. (4) *Geodetic errors.* The actual surface of the earth is an oblate spheroid, mathematically approximated by an ellipsoid of revolution, the equatorial radius being greater than the polar. Any missile using **accelerometers**, even though these operate properly, will not measure in its flight the correct distances to the target, since these are not known accurately enough according to available surveys of undulations of the surface of the earth from the theoretical surface assumed for map projections and coordinate systems.

ACCELEROMETER, INTEGRATING. A device whose output signals are proportional to the velocity of the vehicle or to the distance traveled (depending on number of integrations) instead of acceleration. (See figure.) When installed in a rocket the integrating accelerometer may be preset to switch off the fuel flow (thrust) when the required speed is reached.



Schematic of a navigational accelerometer and integrator.

ACCELEROMETER MATCHING. A method of aligning two remote reference systems; e.g., stabilized platforms, by comparing the outputs of two identically-oriented **accelerometers** while the two systems are experiencing the same motions.

ACCEPTABLE RELIABILITY LEVEL. The required level of reliability for a part, system, device, etc. It may be expressed in a variety of forms, as for example, in the number of failures allowable in 1000 hours of operating life.

ACCESS TIME. (1) The time interval, characteristic of a memory or storage device, between the instant at which information is requested of the memory and the instant at

which this information begins to be available in useful form. (2) The time interval between the instant at which information is available for storage and the instant at which it is effectively stored.

ACCOMMODATION. In air medicine, the functional adjustment of the body to environmental changes.

ACCUMULATOR. (1) In computer applications, a device which stores a number, and upon reception of a new number, adds it thereto and stores the sum. An accumulator may have properties such as shifting, sensing signs, clearing, complementing, etc. (2) An apparatus for storing a volume of fluid under pressure for the purpose of actuating pressure-operated devices in hydraulic or pneumatic mechanisms. In this way there is provided a ready supply of usable fluid at or close to the working pressure of the system, and in sufficient quantities to cover heavy demands for short periods of time. Such quantities may not be within the capabilities of the pumping system to provide without undesirable build-up time. An accumulator is usually a spherical or hemispherical hollow object containing diaphragms or bladders of various sorts to control the fluid collected. Accumulators are also used to supply limited amounts of fluid to operate emergency circuits in the event of failure of primary pumping devices, or to damp pressure surges in order to prevent damage to sensitive regulators or other components. (3) A British term for a storage (secondary) battery.

ACCURACY. (1) The quality of correctness or freedom from error. It is distinguished from "precision" as shown by the following example: "this procedure measures the precision (reproducibility) of the test, not its accuracy (closeness to the true value)." In keeping with the preceding general definition, the accuracy of an instrument is a number or quantity which defines its limit of error. (See also **precision**.) Thus in electrical measuring instruments, accuracy is often expressed as a percentage of full scale, referring to the maximum deviation of the measuring instrument. For example, an accuracy of 5% of full scale would amount to an assurance of exactness of ± 5 volts if full scale were 100 volts. (3) The accuracy of a missile system is its ability to impact within some defined standard distance

of the target. (4) The accuracy of a system or component is the extent to which it operates within the design limits defined for that particular device. (See also **errors**, **circular error probable**, **single shot hit probability**, **survey accuracies**.)

ACCURACY, ABSOLUTE. The closeness of a measured value to the "true" value, regardless of the process of measurement used. Absolute accuracy is measured from the standard origin of values, assuming that no errors in measuring exist, i.e., assuming the existence of a perfect tool, device or method of measurement.

ACHROMATIC. In optics: (1) Free from hue. Thus, an achromatic color is one of the shades of gray between white and black. (2) Transmitting light without showing its constituent colors, or separating it into them. Thus, an achromatic lens system is free from **chromatic aberration**.

ACKERET THEORY. A theory of supersonic flow past an infinite wing, which disregards all terms in the aerodynamic equation that are of higher than first order. This theory assumes the following conditions: (1) That all parts of the wing surface are inclined at a small angle to the direction of flow, thus implying that the leading and trailing edges are sharp, and that both the incidence and thickness ratio of the wing are small; (2) That the bow wave is attached to the leading edge of the wing; and the tail wave, to the trailing edge; (3) That each element of wing surface acts independently of all others. The **Busemann theory** of supersonic flow includes the second order terms as well as the first.

ACOUSTIC. Containing, producing, arising from, actuated by, or carrying **sound**; or designed to carry sound and capable of doing so.

ACOUSTIC DELAY LINE. Delay line.

ACOUSTIC DISPERSION. The separation of a complex sound wave into its various frequency components, usually caused by a variation with frequency of the **wave velocity** of the medium. The rate of change of the velocity with dispersion is used as a measure of the dispersion.

ACOUSTIC IMPEDANCE. Impedance, acoustic.

ACOUSTIC REACTANCE. Reactance, acoustic.

ACOUSTIC SPEED (SONIC SPEED). The speed with which sound waves and small pressure disturbances are propagated. It is expressed by the relationship:

$$a = V/M = \sqrt{gkRt}:$$

where a is the acoustic speed, M is the Mach number, g is the acceleration of gravity, k is the temperature constant, R is the gas constant, t is the temperature, and V is the velocity of sound under standard conditions.

ACOUSTIC VELOCITY. Acoustic speed.

ACOUSTICAL. Related, pertaining to, or associated with sound, but not having its properties or characteristics.

ACOUSTICAL STIFFNESS. Stiffness.

ACOUSTICAL SYSTEM. A system adopted to the transmission of sound and consisting of one or more of the following elements; acoustic resistance, acoustical inertance, and acoustic capacitance.

ACOUSTICAL UNITS. Units and dimensions.

ACOUSTICS. In the broadest sense, acoustics is the physics of sound, treated in all its aspects. Commonly, however, the term is restricted to a study of the transmission of sound through various media or in various enclosures or conduits, including the effects of reflection, refraction, interference, diffraction, and absorption.

The investigation of such problems as the passage of sound through simple tubes, or tubes having branches, or through cavities of various shapes, such as musical instruments or resonators, reveals certain remarkable analogies to the theory of a-c circuits; thus one encounters the property known as acoustic impedance; with its components, acoustic resistance and acoustic reactance, the latter being dependent upon the acoustic inertance (analogous to inductance) and acoustic compliance (sometimes called acoustic capacitance). These correspond to analogous properties of a-c circuits in which the electric impulses may be compared to acoustic waves with conductors as the medium. The acoustic

resistance, inertance, and compliance depend, respectively, upon the viscosity, the density, and the elasticity of the medium. (See also entries under sound.)

ACOUSTOMOTIVE PRESSURE. Sound pressure.

ACQUISITION. A radar term denoting the finding and holding of a target.

ACQUISITION RADAR. Radar, acquisition.

ACTINIC. Producing chemical change, a term applied particularly to radiations in the violet and ultraviolet regions of the electromagnetic spectrum which produce photochemical (especially photographic and biological) changes.

ACTINIUM. Radioactive chemical element. Symbol Ac. Atomic number 89.

ACTIVATOR. In general, an agent which markedly enhances a property of a substance or system, or which imparts a property or initiates a process. For example, traces of copper increase markedly the luminescence of zinc sulfide and are therefore called "activators."

ACTIVATOR, INERTIAL. A mechanical device employing springs that absorb energy incident to a velocity change and releases this energy to activate a circuit.

ACTIVE FILTER. Filter, active.

ACTIVE HOMING. Homing in which the homing device reveals its presence, usually by electromagnetic radiation directed at the target.

ACTUATOR. A device which initiates or controls the operation of a mechanism. The term implies an intermittent duty cycle for the mechanism.

ADAPTATION KIT. The equipment needed to install and service a special component or sub-system (for example, a warhead) in a missile. Such equipment includes the fuze, the safety and arming mechanism, the test circuitry and the fittings.

ADAPTATION MANEUVER. In space travel technique, after departure from the earth, absolute coordination cannot be made

with the desired **satellite orbit** unless continuous corrections are applied to the vehicle during the ascent, or unless a series of flight corrections are made just prior to entering the orbit track. The latter is more conservative and comprises the "adaptation maneuver." The purpose of the adaptation maneuver is to insure that the vehicle has the proper velocity and space position to travel to the desired destination, to enter some existing orbit as a concurrent and co-orbital vehicle (e.g., contact a satellite departure station), or to reach the proper position to begin some critical thrust operation before the coasting journey.

ADC. Air Defense Command.

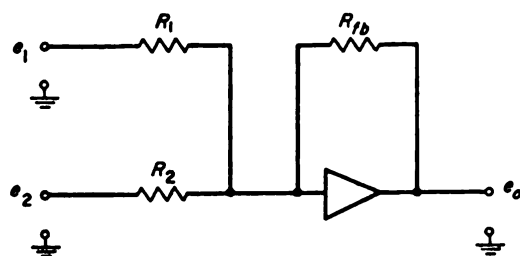
ADCC. Air Defense Control Center.

ADDC. Air Defense Direction Center.

ADDEND. A number which is added to another, called the **augend**.

ADDER. A device which can form the sum of two or more numbers or quantities impressed upon it. These devices are basic components of **computers**. In a *complete adder*, the summation process along with necessary carries is continued to the final result, while in a *half adder* the partial sum is shown without carries. In a *parallel adder*, the summation process occurs simultaneously in all columns of digits, while in a *serial adder*, the summation occurs in the columns consecutively from right to left, as in hand addition.

The operation of adders in large computers is carried out by electrical (or electronic) circuits. A representative addition circuit is shown in the figure.



Addition circuit.

ADDITIVE. An ingredient of a mixture which imparts a new property, or a modification of an existing property that enhances materially the usefulness of the product. For example, in smokeless powder **propellants**, additives are used to fulfil the functions of a

coolant, plasticizer, stabilizer, flash suppressor, coloring agent, inhibitor or opacifier.

ADDRESS. Information (usually a number) which designates a particular location in a memory or storage device, as of a **computer**.

ADIABAT. If a thermally-isolated system moves through a series of equilibrium states, the locus of the points representing these states on a graph is called an "adiabat." Thus in meteorology, an adiabat is a line on a chart showing the adiabatic **lapse rate** (wet or dry).

ADIABATIC. Occurring without change in heat content, i.e., without gain or loss of heat by the system involved. Most gas processes in aerodynamics are adiabatic, and the fundamental process used in all jet propulsion is the conversion of heat energy into kinetic energy by adiabatic expansion.

ADIABATIC COEFFICIENT. The ratio of the specific heat of a gas at constant pressure to its specific heat at constant volume. Designated by the letter γ or k . This coefficient receives its name from the pressure volume relationship of a gas for adiabatic expansions or compressions where

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$

P_1 and V_1 being initial pressure and volume, and P_2 and V_2 the final pressure and volume.

ADIABATIC EFFICIENCY. A measure of the degree to which a change of conditions of a gas approaches the **adiabatic** values.

ADIABATIC EXPANSION. Expansion without gain or loss of heat from outside the substance or system.

ADIABATIC PROCESSES. Changes in matter which take place without transfer of heat.

ADIZ. Air Defense Identification Zone.

ADJACENT-CHANNEL ATTENUATION. Selectance.

ADJACENT-CHANNEL INTERFERENCE. Interference, adjacent-channel.

ADMITTANCE. The reciprocal of **impedance**. Thus if the impedance of a circuit

clement is

$$Z = R + jX, \quad |Z|^2 = R^2 + X^2,$$

its admittance is

$$Y = \frac{1}{R + jX} = \frac{R - jX}{R^2 + X^2} = \frac{R}{|Z|^2} - j \frac{X}{|Z|^2} \\ \equiv G + jB$$

The real part of admittance is called **conductance** (G); the imaginary part, **susceptance** (B). Note that positive reactance implies negative susceptance.

ADVANCE OF THE PERIGEE. Satellite elements.

ADVECTION. The transfer of air and air characteristics by horizontal motion. **Fog** drifts from one place to another by advection. Cold air moves from polar regions southward. Large-scale north-south advection is more prominent in the northern hemisphere than the southern, but west-to-east advection is prominent on both sides of the equator.

ADVECTION FOG. Advection fog is formed when warm moist air comes in contact with a colder surface; this contact with the cold surface cools the air to its dew point, thereby causing condensation and fog. It is a common phenomenon throughout the year over cold ocean currents (for example the Labrador Current) when the air comes from warmer regions.

ADW. Air Defense Warning.

ADWKP. Air Defense Warning Key Point.

AEC. Atomic Energy Commission.

AEDC. Arnold Engineering Development Center; Tullahoma, Tennessee.

AEDD. Air Engineering Development Center.

AEOLIGHT. A type of glow lamp whose illumination is proportional to an applied signal voltage. It consists of a cold cathode inside an envelope of gas at low pressure.

AERIAL. Antenna.

AEROBALLISTICS. A term derived from **aerodynamics** and **ballistics** and dealing primarily with the motion of bodies such as

guided **rockets**, whose path is determined by applying the principles of both sciences, though often to different portions of the path.

AEROBEE. A. U.S. upper atmosphere research rocket vehicle designed by the Applied Physics Laboratory of Johns Hopkins University, Aerojet Engineering Corporation and Douglas Aircraft Company. It is generally considered to be a U.S. Navy missile although all services have used it. It was first fired November 24, 1947 at White Sands Proving Ground. It is 18.8 feet long (plus 6 feet for booster), 15 inches in diameter; it weighs 1665 pounds and carries a payload of 150 pounds. Its integral motor is a nitric acid-aniline gas-pressure fed motor of 2600 pounds thrust designed for a 45 second run. The maximum missile velocity has been 4100 ft/per sec. It can dependably reach an altitude of 70-75 miles. It is launched from a tall (140 feet) tower slightly inclined from the vertical. It carries no internal guidance but is stabilized in flight by three tail fins. Launching is effected by a solid propellant booster delivering 18,000 pounds thrust for 2.5 seconds. The Aerobee has been used for biomedical tests of monkeys and mice under zero-g conditions. The nose cone containing biological subjects is recoverable by means of a ribbon parachute. The Aerobee was also launched from the U.S.S. *Norton Sound* for cosmic ray and magnetometer research made in the vicinity of the northern geomagnetic pole. (See **missile, guided**.) See also illustration facing Page 26.)

AEROBEE HI. A later model high performance **Aerobee**. On 29 June 1956, this Naval Research Laboratory Rocket flew to a height of 163 miles for the single-stage record. This rocket was first fired in August 1955. Missile #6 attained the record. Since it used a booster it was actually a two-stage vehicle. It was 372 inches long with booster, 15 inches in diameter, weighing 269 pounds empty and 1500 pounds at take-off (propellants, 1080 pounds and instruments, 130 pounds). (See **missile, guided**.)

AEROCUTTER. A trade name of the Aerojet General Corporation for any of a family of explosively-activated devices to cut fuel lines, electrical conductors, or tow cables upon receipt of an electrical signal.

AERODYNAMIC CENTER. A point in a cross section of an **airfoil** or other aerodynamic body or combination of bodies, about which the pitching moment remains practically constant with nearly all changes in angle of attack. (Cf. **center of pressure**.)

AERODYNAMIC COEFFICIENTS. A system of non-dimensional coefficients used in **aerodynamics**. The system permits extrapolation of model data to full-scale designs, development of tests, etc.

Lift Coefficient, C_L	$= L/qS$
Nusselt Number	$= hD/\gamma$
Stanton Number	$= \gamma/c_p\mu = 1/Pr$
Moment Coefficient, C_M	$= M/qS$
Drag Coefficient, C_D	$= D/qS$
Reynolds Number	$= \rho VL/\mu$
Prandtl Number	$= C_p\mu/\gamma$
Force Coefficient, C_F	$= F/qS$

Where C_L is the lift coefficient, L is the lift, q is $pV^2/2$, S is the reference area, h is the altitude, D is the drag, γ is the ratio of specific heats, C_p is the specific heat at constant pressure, μ is the viscosity, Pr is the Prandtl number, M is the moment, ρ is the density, V is the velocity, F is the force.

AERODYNAMIC DAMPING. Resistance of motion of a **missile** caused by **aerodynamic forces** acting on the aerodynamic surfaces at a distance from the center of gravity incident to the pitching motion of the missile. The component of lateral velocity of such a surface in combination with the velocity due to forward speed of the missile produces an **angle of attack** which, in itself, provides a restoring moment.

AERODYNAMIC EFFICIENCY. The efficiency with which a body overcomes or makes use of aerodynamic forces or actions; specif., the efficiency with which an airfoil or other lifting body produces lift in proportion to drag, determined numerically from the ratio L/D ($= C_L/C_D$).

AERODYNAMIC FORCE. A force acting on a body in motion through air or other gas, or in relative motion with respect to air or other gas, and arising from this motion. In the case of a missile in flight, the aerodynamic forces and the moments and loads which they produce, are functions of ambient **atmospheric pressure**, flight **Mach number**, and missile size.

AERODYNAMIC HEATING. The heating of a body resulting from the friction of air or other gas against it.

AERODYNAMIC LIFTING SURFACES. **Missile** surfaces which produce normal forces to overcome gravity or to execute a maneuver. Generally they are of either the double wedge, modified double wedge (having a flat section for a certain portion of the chord length) or biconvex cross-sectional profile.

AERODYNAMIC MISALIGNMENT. Fin misalignment.

AERODYNAMIC MISSILE. A missile which uses the reaction of air in some vital, indispensable manner, such as for **lift**. Generally the term means a winged missile and is used in contradistinction to a **ballistic missile**.

AERODYNAMIC REPORT. A document covering the available detailed aerodynamic information pertinent to the design and operation of a **missile**. Data in this report are obtained from the results of theoretical calculations, wind tunnel and ballistic range tests, and, where possible, results of flight tests, which may be available at the time the report is written and which apply to the design. The report contains the results of all analytical work carried out in obtaining the stability and control characteristics, that is, the stability derivatives and coefficients in terms of lists of these slopes and constants for various flight conditions. The overall aerodynamic operational characteristics of the design are shown. Such a report is usually broken down into divisions covering (a) the **missile** external aerodynamic characteristics, (b) the engine characteristics (in the case of **ramjets** or **turbojets**, but not with rockets, and (c) the overall performance characteristics.

AERODYNAMIC RESPONSE. The flight path and flight **attitudes** taken by a body moving in air (or other gases) following the application of control forces.

AERODYNAMIC TEST VEHICLE. A flight test vehicle designed specifically to obtain aerodynamic data. It is most commonly used during the development phase of a **missile** program.

AERODYNAMIC TOLERANCES. Parametric boundaries which have adverse aerodynamic effects if exceeded.

TYPICAL MANUFACTURING TOLERANCES FOR GUIDED MISSILES

Struts	Ordinate ± 0.032
Diffusers	Ordinate ± 0.032 (on radius)
Innerbodies	Ordinate ± 0.032 (on radius)
Nozzles	Ordinate ± 0.064 (on radius)
Body O.D.'s	Ordinate ± 0.064 (on radius)
Innerbody displacement and concentricity relative to lip of diffuser for multiple shock entry designs	± 0.032
Innerbody angular misalignment	$\pm \frac{1}{2}^\circ$
Longitudinal body station location	$\pm \frac{1}{32}$
Longitudinal location of aerodynamic surfaces, scoops and exit nozzles	± 0.25
Normality of mating surfaces	$\pm 0^\circ 5'$
Diameter of mating surfaces	± 0.010
Out of round mating surfaces	± 0.06 T.I.R.
Thickness of surfaces	$\pm 2\%$ of total specified thickness or 0.30, whichever is larger
Aerodynamic surface planform dimensions	± 0.064
Clearance— aerodynamic surfaces to body O.D.'s at any point	
Movable surfaces	0.06 to 0.25
Fixed surfaces	0.01 to 0.20
Fairness—differences between actual deviations from theoretical contour	0.32 in any 3" of length
Camber (all surfaces) maximum deviation of the mean thickness line at midchord from theoretical chord plane through leading and trailing edge	0.3% chord or 0.03, whichever is larger
Radius of all corners in plan view unless otherwise specified	0.10 \pm 0.05
Wing tip radii, plan view	0.25 \pm 0.06
Leading and trailing edge thickness in cross section all surfaces	0.04 \pm 0.010 — 0.015
if rounded, radius	0.020 \pm 0.005 — 0.015
if square, break corners	0.005 to 0.015

AERODYNAMIC TRAJECTORY. Ballistic trajectory.

AERODYNAMICS. That branch of fluid dynamics concerned with the motion of the air and other gaseous fluids and with the forces acting on solids immersed in such fluids. It deals especially with the theories of flight of both lighter-than-aircraft and craft depending

upon the reaction of airfoils during relative motion in the air for support and control.

AERODYNE. (1) A variation of aerodynamic (the literal meaning is "air force"). (2) In a seldom-used general sense a term which denotes any heavier-than-aircraft (glider, helicopter, or conventional airplane as contrasted to a rocket). (3) Specifically, a

term denoting a type of tubular wingless jet-propelled aircraft supported and maneuvered principally by thrust-vector deflection. The lift derived from the configuration is not sufficient to support it without power.

AEROELASTIC EFFECTS. Structural deformations due to aerodynamic forces (See **aeroelastics**). The magnitude of aeroelastic effects for any particular airframe configuration at a particular flight condition will depend on (a) the dynamic pressure q , (b) the trim conditions (which are in turn affected by location of the center of gravity and by **Mach number**, (c) structural rigidity and (d) normal acceleration. Aeroelastic effects are predominately influenced by variations in dynamic pressure and may be expected to be most serious at low altitude and high Mach number.

AEROELASTICITY. The study of the interaction of **aerodynamic**, elastic, structural and inertia forces. (See **aeroelastics**.)

AEROELASTICS. The study of aircraft structures in which the interaction of elastic deformations in structural elements and the aerodynamic loadings upon these elements are used in structural design and in evaluating stability and control.

AEROEMBOLISM. Air "bends." The decompression sickness of deep-sea divers caused by bubbles of nitrogen forming in the blood and thereby affecting the operation of the heart. The same difficulty is likely to arise in space emergencies where rapid decompression occurs. For space ships it is planned to create the artificial atmosphere of the cabins without nitrogen in order to avoid this biological hazard.

AEROEMPHYSEMA. An altitude decompression sickness brought on by the formation of gas bubbles in the connective tissues. (Cf. **aeroembalism**.)

AEROGRAPH. An instrument carried aloft by a balloon or airplane to record automatically and simultaneously such meteorological parameters as barometric pressure, temperature, and humidity.

AEROLOGY. A branch of **meteorology** having to do with the study of the atmosphere.

AEROMARKER. A trade name of the Aerojet General Corporation for a device for pro-

ducing a visible flash of light and a dense puff of smoke from a **missile** in flight. The puff is radar-reflective.

AEROMETER. An instrument used to measure the **density** (or some other property) of the atmosphere.

AEROMETEOROGRAPH. An instrument made for carrying in an aircraft for the purpose of making an "air sounding," i.e., an investigation of the atmospheric conditions at various levels. The instrument makes a running record of atmospheric pressure, temperature and relative humidity at the various altitudes reached by the aircraft in flight.

AERONAUTICAL CHART. (1) A chart or map representing a given area of the earth's surface and used in air navigation. (2) A universal plotting chart.

AERONAUTICAL MILE. Same as **nautical mile**, 6080 feet.

AEROPAUSE. A region of indeterminate limits in the upper **atmosphere**, considered as a boundary or transition region between the denser portion of the atmosphere and outer space. From a functional point of view, it is considered that region in which the atmosphere is so tenuous as to have a negligible, or almost negligible, effect on men and aircraft. In the aeropause the physiological requirements of man and the substitution of jet reaction for aerodynamic forces become increasingly important in the design of aircraft and auxiliary equipment.

AEROPLEX. The trade name for a small rocket motor produced by Aerojet General Corporation.

AEROPULSE. A propulsive jet device producing thrust intermittently from intake of air as distinct from water, as in the hydro-pulse. (See **pulse jet**.)

AERORESONATOR. **Pulse Jet**.

AEROSOL. A **colloidal system** in which a gas, usually air, is the vehicle, and particles of useful solid or liquid are dispersed in it.

AEROSOUND. A rocket designed by Aerojet General Corporation for their proposed **Rockair** launching scheme. The system consists of a 1.8Ks7800 solid propellant

motor with nose cone clusters of these rockets in a two-stage configuration weighing approximately 12,500 pounds. It is believed able to carry 250 pounds to 90 miles, or with a third stage to carry 50 pounds to 490 miles.

AEROSPACE. Of or pertaining to the earth's envelope of atmosphere and the space above it, the two considered as a single realm for activity in the launching, guidance, and control of **ballistic missiles**, **earth satellites**, **dirigible space vehicles**, and the like.

AEROSPHERE. (1) A non-rigidly defined part of the atmosphere of density sufficient to support aerodynamic flight. (2) That part of the atmosphere in which manned flight is currently possible.

AEROSTAT. A general term referring to all types of **lighter-than-aircraft**.

AEROSTATICS. (1) The science of gases at rest (mechanical equilibrium) and of forces acting on bodies in them. (Cf. **aerodynamics**, the science of gases in motion.) (2) The techniques of navigating **lighter-than-aircraft**.

AEROTHERMODYNAMICS. The science dealing with aerodynamic phenomena and relationships (see **aerodynamics**) under conditions at which thermal effects, especially changes in heat content, becomes significant. Such conditions commonly occur, for example, at supersonic velocities or during compressible flow.

AEROTOJET. A type of **rocket motor** in which the thrust chamber is mounted on a shaft which can rotate. The motor is tilted with respect to the axis of the shaft. When the motor fires the shaft turns. Power is taken from the shaft to drive the propellant pumps. The idea was explored by the Aerojet Engineering Corporation but was dropped as impractical.

AEW. Airborne Early Warning.

AF. Audio frequency.

AFAC. Air Force Armament Center; Eglin Air Force Base; Valparaiso, Florida.

AFBMD. Air Force Ballistic Missile Division.

AFC. Automatic Frequency Control.

AGC. Automatic Gain Control.

AFCRC. Air Force Cambridge Research Center; Laurence G. Hanscom Field; Bedford, Massachusetts.

AFFTC. Air Force Flight Test Center; Edwards Air Force Base; Edwards, California.

AFMDC. Air Force Missile Development Center; Holloman Air Force Base; Las Cruces, New Mexico.

AFMTC. Air Force Missile Test Center; Patrick Air Force Base; Cocoa, Florida.

AFOSR. Air Force Office of Scientific Research; Washington, D.C.

AFPO. Air Force Procurement Officer.

AFPR. Air Force Plant Representative.

AFPTRC. Air Force Personnel and Training Research Center; Lackland Air Force Base; San Antonio, Texas.

AFOSR. Air Force Office of Scientific Research.

AFSWC. Air Force Special Weapons Center; Kirtland Air Force Base; Albuquerque, New Mexico.

AFSWP. Air Force Special Weapons Project.

AFTERBODY. The tailward portion of a **missile** beyond a given reference point. For example, in missiles consisting of a nose cone and cylindrical body, the latter is often denoted as the afterbody.

AFTERBURNER. A second **combustion chamber** installed as an extension to a reaction engine through which the primary engine exhaust passes. In this second chamber additional fuel is injected into the exhaust gases and additional burning is induced to derive increased thrust from the already hot and accelerated engine gases. The afterburner is used with the **turbojet** engine for additional thrust for short periods where super-performance is needed (such as take-off and during combat). It is a highly inefficient system and undesirably increases the length of the engine to which it is attached. This thrust-augmentation technique is also known as "tailpipe

burning.” (See also **P-V diagram** and **turbo-jet**.)

AFTERBURNING. (1) The characteristic of certain **rocket motors** to burn irregularly for some time after the main burning and thrust have ceased. (2) The process of operation of an **afterburner**.

Ag. Silver.

A-G. Aerojet General Corporation, Azusa, California.

AGARD. Advisory Group for Aeronautical Research and Development.

AGC. Automatic Gain Control.

AGENT. A force or substance that acts to produce a change.

AGM. Air-to-ground missile. (See **missile, air-to-ground; missile, guided; model designation**.)

AGONIC. (1) Without angles. (2) Without **magnetic variation**.

AGONIC LINE. An imaginary line on the earth's surface, or a line shown on a chart, connecting points of zero **magnetic variation**. (See discussion of **isogonic line**.)

AGRAVIC. Without gravity, i.e., in a region or under conditions in which the resultant gravitational field is essentially zero.

AI. Air intercept radar. (See **radar, air intercept**.)

AIA. Aircraft Industries Association.

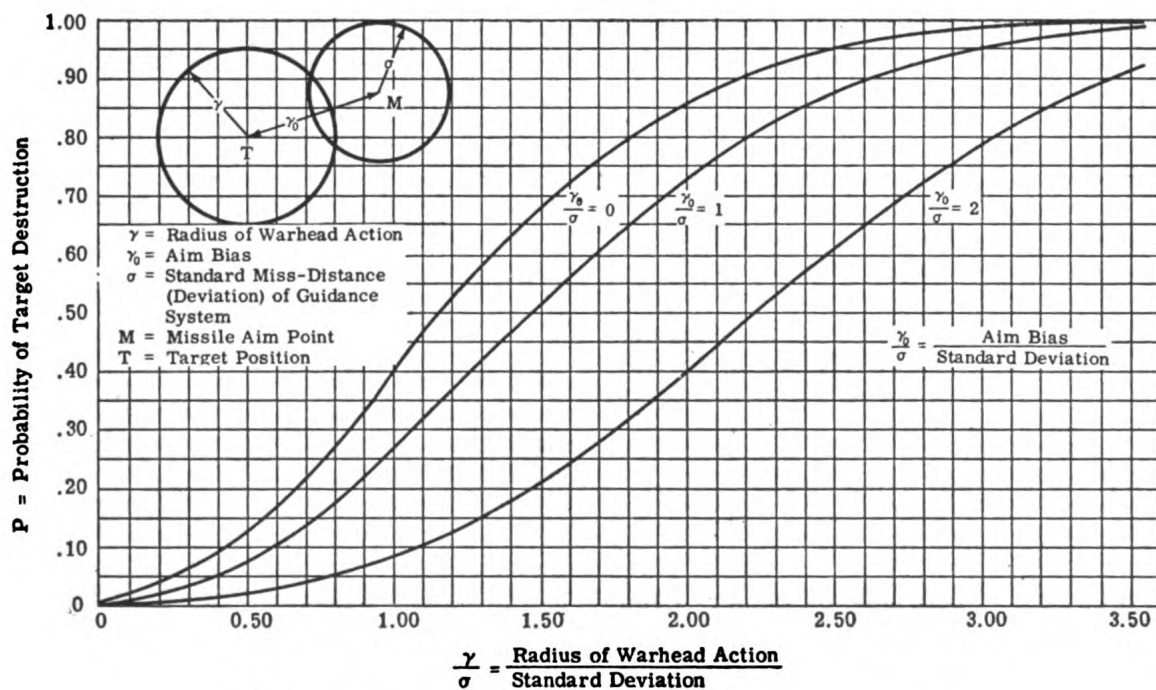
AICBM. Anti-intercontinental ballistic missile.

AIDED TRACKING. A system, or the action, of tracking a moving object in bearing, elevation, or range (or any combination of these) by means of a semiautomatic radar tracking mechanism.

AIEE. American Institute of Electrical Engineers.

AIGS. All-inertial guidance system.

AILERON. A movable **control surface** on an **airframe** which produces the forces necessary to cause rotation of the airframe about its longitudinal axis. This motion, known as “roll,” is used to correct other rolls produced by external conditions, such as gusts. It is also used to accomplish such maneuvers as banks or sideslips.



Relationship of armament effectiveness and guidance accuracy.

AILERON ANGLE. The acute angle between the chord of an aileron moved from its neutral position and its chord in neutral position.

AIM-BIAS. The error between the aiming point and the dispersion center of a statistical sample of missile trajectories. (See figure.)

AIMING CIRCLE. A rough surveying instrument used in the military artillery services for laying the gun battery, making position area surveys and other uses where measurements are needed. It is a very small lightweight instrument, completely portable in one unit with its own water-protective case. When properly set up its legs are extended about 6 inches and the vertical sliding support under the telescope head is extended at least one inch. It is thus necessary to operate the instrument from a kneeling position. The instrument has two "lower" motions, one fast and one slow. The "upper" motions (also fast and slow) are used to measure the angles. Readings on the instrument are in **mils**. The main scale is numbered in 200 mil increments from "0" to "6400." Fine measurements to one mil are read from a vernier knob meshed into the traversing gear train. **Azimuth** readings are indicated by a magnetic needle in the head. Vertical angles can be read by leveling the telescope and then turning an elevating knob until the instrument's cross-hairs are aligned with the desired point.

AIMING ERROR. An error in missile launching caused by miscalculation of such factors as longitude, latitude, distance, speed or re-entry deflection. (Cf. **circular probable error**.)

AIMING POINT. The desired impact point at which a missile is aimed.

AIR. The mixture of gases and other materials forming the atmosphere of the earth. The earth's atmosphere consists of a vast body of gases, vapors and suspended matter, which extends to a height which can be expressed only in terms of particular effects, e.g., having different limiting values for the **twilight arch**, for **meteor trails** and for the **aurorae**. In general, it becomes more attenuated and its composition changes at increasing distances from the surface of the earth. Properties of dry air at normal temperature

and pressure, which is 15°C and 14.7 lb per sq. in., are as follows:

- C_p (Specific heat at constant pressure)
= 0.2399 B.T.U. per pound per °F.
at 32°F and 1 atmosphere pressure
- C_v (Specific heat at constant volume)
= 0.1713 B.T.U. per pound per °F.,
at 32°F. and 1 atmosphere pressure.
- γ (adiabatic coefficient or the ratio: C_p/C_v)
= 1.400. (This varies with temperature and pressure)
- R (gas constant = $C_p - C_v = C_v(\gamma - 1)$)
- μ (coefficient of viscosity) = 3.781×10^{-7}
slug ft⁻¹ sec⁻¹
- ν (kinematic coefficient of viscosity)
= $\mu/\rho = 0.000159$ ft² sec⁻¹; at 0°C
= 0.000152 ft² sec⁻¹; at 100°C
= 0.000194 ft² sec⁻¹
- ρ (density) = 0.0764 lb. per cu. ft.
- σ (Prandtl's number) = $\mu C_p/\gamma = 0.715$

Composition; (Average in percentage by volume):

Nitrogen	78.09%
Oxygen	20.93%
Argon	0.93%
Carbon dioxide	0.03%
Balance (consisting of neon, helium, krypton, hydrogen, xenon, ozone and other components)	0.02%

Note again that the above data are given for dry air at about standard conditions at sea level.

AIR ALMANAC. A publication issued three times a year as a combined effort by the U.S. Naval Observatory and the British Royal Greenwich Observatory, containing astronomical data pertaining to air navigation.

AIR BEARING. A system of lubrication of precision bearings using low pressure air continuously flowing around the bearing surfaces as the lubricating fluid. One type consists of a plain journal bearing lubricated with compressed air through a number of fine holes around the journal. Such a bearing must be precision-machined so tightly that it is practically immovable with the air off (e.g., 0.002 inches clearance). When the air is flowing it is so free that friction is almost negligible. Other gases may also be used.

AIR BREATHER. A rocket, missile or airplane that consumes air in its operation—principally as an oxidant.

AIR BREATHING. Taking in air for purposes of combustion.

AIR BURST. The explosion of a nuclear weapon in the air, above land or water, at a height greater than the maximum radius of the fireball.

AIR CURRENT. A stream of air moving in any direction other than horizontal, especially in the vertical.

AIR DEFENSE SYSTEM. A weapon system whose mission is to defend a target complex from air attack; usually it includes an early-warning **radar** and **ground observer network**, interceptors, surface-to-air **guided missiles**, rockets and conventional AA guns.

AIR DENSITY. The mass per unit volume of air which, however, is sometimes expressed as weight per unit volume. An important relationship is that between air density and its frictional heating effect upon objects moving through the air. While for most density values, this heating decreases with decreasing density, this relationship changes at the very low densities encountered at extremely high altitudes. This change is believed due to the behavior, under such conditions, of the air as separate particles rather than a continuous medium.

AIR GAP. (1) This term is commonly used in connection with various **magnetic circuits**, and denotes a gap left in the magnetic material. In the construction of various **chokes** and **transformers** used in communications circuits, a short gap is usually left in the core material to prevent the material being saturated by the d-c which often flows in such circuits. (See **amplifiers** and **power supplies**.) In rotating electrical machinery the rotating part of the magnetic circuit must of course, be separated by a gap. In these machines this gap is kept as small as consistent with adequate mechanical clearance. In most instances the gap introduces no desirable electrical or magnetic characteristics, and necessitates the application of additional electrical **magnetomotive force** to overcome its **reluctance**. (2) A spark gap, comprising two conducting electrodes, separated by air.

AIR LOCK. (1) A compartment capable of double sealing on one side from the exterior, and on the other from the space-ship interior. The small chamber may be evacuated or filled with breathing atmosphere independently of the main pressurized compartments in such a way as to retain the main air supply, yet allow access into, and exit from the ship into the surrounding environment. (2) A stoppage or interruption of proper flow of fluid in an oil line or fluid system, especially in a hydraulic system, caused by trapped air.

AIR LOG. A device used to measure distance traveled through the air, and consisting in its most common form of a small accurately-pitched propeller geared to a revolution-counter. It is used in certain **guided missiles** to control range.

AIR MASSES. Very large parcels of air ranging from about 500-5000 miles in lateral dimensions and from several thousand feet to several miles deep, which have properties (temperature, humidity, thermal structure) that vary only slightly, or vary linearly, from horizontal point to point within the parcel. Air masses develop over large, relatively-homogeneous geographical areas where air is stagnant for a sufficient period to acquire the characteristics of that region. These regions are either continental or maritime and are known as air-mass source regions. After an air mass begins to move from its source region it acquires modifying features characteristic of the surface over which it travels. Modification continues until the air mass loses its identity in the general atmospheric circulation.

Classification of air masses begins from latitudinal consideration. There are four major zones which contribute primary classifications: (1) Arctic, (2) Polar, (3) Tropical, (4) Equatorial.

These are subdivided into Maritime (m) and Continental (c), depending upon the exact source region. Finally each air mass must be classified as either cold (k) or warm (w). A cold air mass is one which is colder than the surface over which it is traveling and is therefore being heated from below. A warm air mass is one which is warmer than the surface over which it is traveling and is therefore being cooled from below.

AIR MONITOR. Any device for detecting and measuring airborne radioactivity for warning and control purposes.

AIR SCOOP. A scoop or hood designed to entrain and supply air for ballonets, internal-combustion engines, ventilators, etc. The scoop often serves as a **diffuser** in which some of the kinetic energy of flow is converted into a lower speed flow at higher pressure.

AIR SEAL. A partition or gasket, used to block off or stop the flow or passage of air.

AIR SPECIFIC IMPULSE. Specific impulse, air.

AIR SPEED. Airspeed.

AIR VANE. (1) An **airfoil** used to steer or stabilize a **rocket**. Commonly a guidance unit consists of four air vanes. The term is synonymous with **rudder**. (2) In a more general sense, an airfoil used for any purpose other than the principal lift of the airframe.

AIR VECTOR. A vector representing the true heading and true air speed of an aircraft, and forming a part of the **wind triangle**.

AIR WEAPON. A weapon used by an armed service which operates within the atmosphere or in outer space.

AIRCRAFT. (1) In a broad sense, any machine or craft designed to travel through the air or outer space which is given lift by its own buoyancy (as with airships,) or by dynamic reaction of air particles over and about its surfaces, or by reaction to a jet stream or other fluid jet; its propulsion results from acceleration of a portion of the air medium in which it travels (as by a **pulsejet**, **turbojet** or **ramjet**) or by **rocket** action. Strictly, **spacecraft** defines a vehicle for use in outer space. (2) Such a machine or craft regarded as a vehicle, and subject to have its direction changed during flight by the movement of control surfaces or by reaction to a fluid jet. (3) A powered fixed-wing airplane.

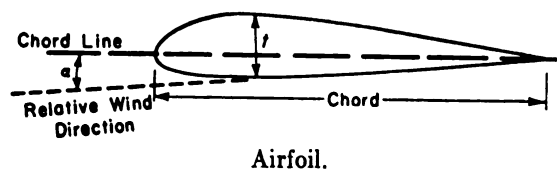
AIRCRAFT ROCKET. A **rocket missile** designed to be carried by, and launched from, an aircraft.

AIRFOIL. (1) A structure, piece, or body, originally likened to a foil or leaf in being wide and thin, designed to obtain a useful

reaction upon itself in its motion through the air. An airfoil may be no more than a flat plate, but usually it has a cross section carefully contoured in accordance with its intended application or function. Airfoils are applied to aircraft, missiles, or other aerial vehicles or projectiles for sustentation (as a wing); for stability (as a fin); for control (as an elevator); and for thrust or propulsion (as a propeller blade). Certain airfoils combine some of these functions. (2) Hence, any such structure or body as a member of an aircraft, missile, or the like, i.e., a wing, rudder, fin, rotor blade, etc. (3) In aerodynamic theory and experiment: (a) such a body as described in sense (1) considered or treated as an independent object, i.e., without reference to the aircraft or other body to which it is applicable, and also without regard to structure—distinguished in this sense from a wing, fin, blade, etc. (b) An airfoil section or profile.

An airfoil is akin to a vane in its operation, but the two are not commonly identified, the distinction arising chiefly from the different purposes to which each is applied.

In aerodynamic theory, an airfoil may also be regarded as a cylindrical body of theoretically infinite length with the axis of the cylinder perpendicular to the direction of the air stream. Mathematical analyses of infinite-length airfoils are modified to develop relations for finite-length ones. In supersonic aerodynamics, the flow over airfoils obeys modified rules. As speeds of aircraft have increased, every attempt has been made to keep the flow over airfoils resembling subsonic flow. Wings have been "swept," "raked" and "clipped" to keep them inside the **Mach cones**



generated by supersonic flow over the wing roots, wing tips, and nose cone. As the flow speed over an airfoil increases into the compressible region, the performance remains dependable until the velocity over its surface reaches the local velocity of sound. Beyond this critical speed there is an almost simultaneous drop in the **lift coefficient**, an increase in the **drag coefficient**, a tendency to dive and according to some indications, a tendency to

roll in one direction or the other, depending upon the configuration. All these changes require that a supersonic airfoil have a different design from a subsonic airfoil. Supersonic airfoils are unavoidably the cause of shock waves which seriously disturb the flow characteristics over the airfoil surfaces. The cambered airfoil necessary for subsonic flight is not necessary for supersonic lift. In supersonic situations, lift is independent of the airfoil section, and a flat plate can be used as a lifting surface, since lift is a function only of the **angle of attack**, increasing with this angle until the critical **stall point** is reached. The most common type of supersonic airfoil is the rectangular double wedge, which for a given **Mach number** provides the least form drag for a fixed thickness ratio. (See also **Compressibility, Supersonic Flow.**)

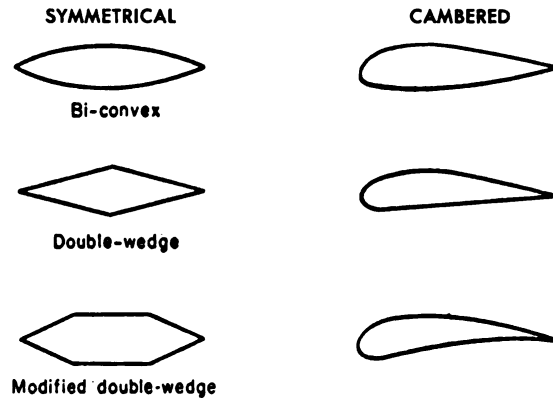
AIRFOIL NOMENCLATURE. The NACA nomenclature designating a wing cross-section consists of four digits. The first digit indicates the **camber** of a **mean line** in percent of **chord**, the second shows the position of the maximum camber of the mean line in tenths of the chord from the leading edge, and the last two digits indicate the maximum thickness in percent of the chord. For example, a NACA2315 profile has a maximum camber of 2% of the chord at a position 0.3 of the chord from the leading edge, and a maximum thickness of 15% of the chord.

AIRFOIL PROFILE. The outline or shape of an **airfoil** section. It refers to the general outline of the airfoil in descriptive terms, such as wedge, double wedge, modified double wedge, and biconvex. (See figure.)

AIRFOIL SECTION. The cross-section of an airfoil cut along a line parallel to the direction of intended flight. The term is loosely interchangeable with **airfoil profile**, but implies a more rigorous, or even dimensional, statement.

AIRFRAME. The principal structural portion of an air vehicle, less propulsion system, control and guidance equipment and payload. The airframe is bounded by the surface of the vehicle which is in contact with the air, and usually includes only the primary structure.

AIR-FUEL RATIO. The ratio by weight of air to fuel used in an air-burning engine. In



Typical airfoil profiles.

rocket engines the same concept is expressed in the fuel-to-oxidizer ratio. In hydrocarbon-air combustion engines this ratio is approximately 16:1.

AIRGLOW. A glow or light of the upper **atmosphere**. At night the airglow amounts to approximately five times the amount of starlight received by the earth.

AIR-LAUNCHED. Launched from an air vehicle in flight.

AIR-MASS FOG. A fog occurring in an air mass, in which the principal factor for formation is cooling of the air to its **dew point**, caused by **advection**, or by **radiation**, or by both.

AIRONE. An unguided air-to-air proximity-fuzed **rocket** manufactured by Polverifici Stacchini, Rome, Italy.

AIRPLANE. (1) Any heavier-than-air aircraft supported by the dynamic reaction of air flowing over fixed or rotating plane surfaces (as distinguished from aerostats), including the piston-driven and the jet airplanes, the glider, helicopter, gyroplane, and the winged **guided missile**. (2) A power-driven aircraft having a fixed wing or an adjustable fixed wing. (3) Any winged aircraft, including the guided missile.

AIRPORT SURVEILLANCE RADAR. A radar set or system used in conjunction with a ground-controlled approach system to detect aircraft within a certain radius of an **air-drome** and to present continuously to the controller information as to the position, in distance and azimuth, of such aircraft.

AIRSHIP. A dirigible.

AIRSPEED. The velocity of a body traveling in the atmosphere measured with respect to the air as a reference.

AIRSPEED, CALIBRATED. The airspeed as read from a differential-pressure airspeed indicator which has been corrected for instrument and installation errors. Equal to true airspeed for standard sea level.

AIRSPEED EQUIVALENT. The product of the true airspeed and the square root of the local atmosphere density ratio ρ/ρ_0 . The term is used in structural design work to designate various design conditions.

AIRSPEED HEAD. An instrument which, in combination with a gauge, is used to measure the speed of a vehicle relative to the air. It usually consists of a pitot-static tube or a pitot-venturi tube.

AIRSPEED, INDICATED. The airspeed as indicated by a differential-pressure airspeed indicator, uncorrected for instrument and installation errors.

AIRSPEED, TRUE. Calibrated airspeed corrected for altitude effects, i.e., pressure and temperature, and for compressibility effects where supersonic speeds are concerned. Not to be confused with ground speed.

AIR-SURFACE. Between aircraft and the surface of the earth; occurring or going between the air and the surface of the earth, as in air-surface communication; designed or designated for use between the air and the surface, as in air-surface missile.

AIR-TO-AIR. Occurring or going between one place and another in the air, or between aircraft, as in air-to-air communication, air-to-air gunnery; designed or designated for use between aircraft, as in an air-to-air guided missile.

Al. Aluminium.

ALBEDO. (1) A measure of the reflecting power of an object, defined as the ratio of the radiation reflected from an object to the total amount incident upon it. The albedo of the moon is about 7%, which is about the same as that of slate, lava or similar dark-colored rocks. The albedo of the earth is

estimated at 50%, but local reflections from water surfaces have values as great as 75-80%. For the albedos of other planets, see planet. (2) The ratio of the neutron current density out of a (non-source) medium to the neutron current density into it. (3) Energetic charged secondary cosmic rays which move generally upward. Since some of them go far into the upper atmosphere and return to the earth's surface (because of the effect of the earth's magnetic field), measurement of primary cosmic radiation must be corrected for the contribution of the albedo particles.

ALBERPORTH. A small English guided missile range on the Welsh coast. It comprises approximately 250 acres, with a total of 70,000 yards of range instrumentation.

ALCOHOL. An organic chemical compound containing a hydroxyl group ($-OH$), attached to a non-benzenoid carbon atom. Alcohols used as rocket propellants include ethyl alcohol, methyl alcohol and furfuryl alcohol. Often the word alcohol is applied to ethyl alcohol.

ALEE. Toward the leeward (i.e., downwind) side.

ALFEN WAVE. A magnetohydrodynamic wave, produced by coupling between mechanical and electromagnetic forces in space. This coupling is due to the fact that the medium (i.e., the interplanetary gas) is an electrical conductor so that any hydrodynamic reaction causes induced electric fields which, in turn, produce a current. By reaction with the geomagnetic field, this current produces force, and hence motion. Gold has suggested the concept of an interplanetary shock front, in order to explain the near simultaneity on a planetary scale of the sudden commencement of magnetic storms after the long (some 20 hours) travel time of the beam of ionized particles from the sun.

ALGAE. Many different kinds of plants, including the pond-scums and most seaweeds. Botanically, they are thallophytes characterized by possessing chlorophyll, and so capable of elaborating their food by photosynthesis. They are important as a possible means of air purification in satellites or space ships, since these plants use carbon dioxide as food for their growth, giving off free oxygen

in the process. The algae are also a potentially rich source of protein for food. The carbon dioxide-oxygen cycle of algae is not entirely self-sustaining, that is, a small amount of oxygen must be provided to maintain it. Moreover, they must be exposed to sunlight or other light containing the required frequencies of radiation. For short duration space flights, the necessary equipment is likely to be too bulky.

ALIDADE. An instrument, consisting of a rule with a telescopic or with slit sights, that is used as a means of accurate sighting in **plane table** surveying. The alidade is laid on the plane table, and true directions to distant objects can be plotted directly by drawing lines along one edge of the rule after it has been sighted.

ALIGNING. In radio or electronics, the process of lining up or adjusting two or more resonant circuits, so they will give satisfactory response to the given frequency.

ALIGNMENT STATION. A concrete structure housing the equipment to align a missile to its proper **azimuth**, and to reference its **gyroscope** platforms.

ALKYL GROUP. A group of atoms formed from an aliphatic **hydrocarbon** by eliminating an atom of hydrogen.

ALL-PASS NETWORK. **Network, all-pass.**

ALLOWABLE FLUTTER SPEED. The speed at which **flutter** may occur without undue hazard to the mechanism or system. Good practice indicates that flutter speed should exceed maximum operating speed by at least 25 percent.

ALLOWABLE STRESS. If a member is so designed that the maximum stress as calculated for the expected conditions of service is less than a definite value, the member will have a corresponding margin of security against damage or failure. This definite value is the allowable stress, which in engineering practice depends upon the nature of the stress, the kind of material and the service conditions. In general, the margin between allowable stress and damaging stress will be increased by uncertainty as to the conditions of service, by nonuniformity of the material, and by inaccuracy of stress analysis.

ALLOWANCE. Authorized number of personnel or amount of material items normally allocated to a military or naval unit.

ALLOY. Generally speaking, a macroscopically homogeneous mixture of metals. This definition covers an immense class of materials of great technological importance. There are various types of alloys. Thus, the atoms of one metal may be able to replace the atoms of the other on its lattice sites, forming a substitutional alloy, or solid solution. If the sizes of the atoms, and their preferred structures, are similar, such a system may form a continuous series of solutions—otherwise the miscibility may be limited. Solid solutions, at certain definite atomic proportions, are capable of undergoing an order-disorder transition into a state where the atoms of one metal are not distributed at random through the lattice sites of the other, but form a superlattice. Again, in certain alloy systems, intermetallic compounds may occur, with certain highly complicated lattice structures, forming distinct crystal phases. It is also possible for light, small atoms to fit into the interstitial positions in a lattice of a heavy metal, forming an interstitial compound. (See also **metals and alloys**.)

ALPHA. A general term used by the IGY (International Geophysical Year) to designate, by the addition of coded numbers, various satellites and satellite carriers. Thus, Alpha 57-1 designates the **Sputnik I** rocket carrier; Alpha 57-2 designates the **Sputnik I** satellite and Alpha 58 designates **Explorer I**.

ALPHA CHAMBER. A counter tube or counting chamber for the detection of **α -particles**; often operated in the non-multiplying (**ionization chamber**) or **proportional region** with pulse height selection to discriminate against pulses due to **β -** or **γ -rays** and to pass only those due to **α -particles**.

ALPHA CHANGE. A nuclear change consisting of the emission of an **α -particle**.

ALPHA COUNTER. A system for counting **α -particles** including an **α -counter tube**, amplifier, pulse height discriminator, scaler and recorder, or the **α -counter tube** plus the necessary auxiliary circuits for counting **α -particles**. Often loosely applied to the **α -counter tube** or chamber alone.

ALPHA COUNTER TUBE. A counter tube or counting chamber for the detection of α -particles. (See α -counter.)

ALPHA DISINTEGRATION. A nuclear process, consisting of the emission of an α -particle from a nucleus, producing a decay product consisting of a nuclide with an atomic number two units smaller, and a mass number four units smaller than the original nuclide.

ALPHA DISINTEGRATION ENERGY. (1) The energy of disintegration of an α -disintegration process, equal to the value $Q_\alpha = E_\alpha + E_R$ where Q_α is the α -disintegration energy, E_α is the kinetic energy of the α -particle, and E_R is the recoil kinetic energy of the product atom. If M_α and M_R are the masses of the α -particle and the recoil atom, respectively, then

$$E_\alpha = \frac{M_R}{M_R + M_\alpha} Q_\alpha.$$

and

$$E_R = \frac{M_\alpha}{M_R + M_\alpha} Q_\alpha.$$

(2) Often, the ground state α -disintegration energy, which is the total energy evolved, including the energy of gamma and associated radiations, when the disintegrating and product nuclei are in their ground states: $Q_{\alpha 0}$.

ALPHA EMITTER. A radionuclide that undergoes a transformation by α -particle emission.

ALPHA PARTICLE. (1) A positively-charged particle emitted from an atomic nucleus and composed of two protons and two neutrons. It is identical in all measured properties with the nucleus of a helium atom. (2) The nucleus of a helium atom (atomic number, 2; mass number, 4) especially when in rapid motion, as when artificially accelerated. Alpha particles have great ionizing power and are dangerous to living tissue. However, they have little penetrating power, and so are readily shielded.

ALPHA RAY. α -particle.

ALPHADUCT. A type of flexible non-metal conduit for electrical wiring.

ALTAZIMUTH. An optical instrument that is capable of being elevated and traversed so

as to measure angles in both the vertical and horizontal planes. The most familiar altazimuth instrument is the ordinary surveyor's transit or theodolite.

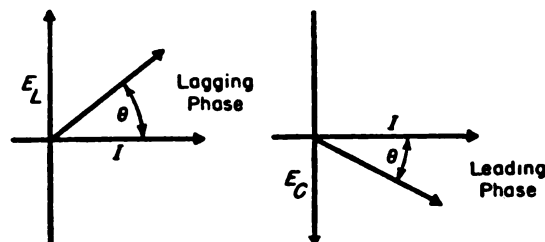
ALTERNATING CURRENT (A-C). Current in which the charge-flow periodically reverses, as opposed to direct current, and whose average value is zero. Alternating current usually implies a sinusoidal variation of current and voltage. This behavior is represented mathematically in various ways:

$$I = I_0 \cos(2\pi ft + \phi)$$

$$I = I_0 \angle \phi$$

$$I = I_1 e^{j\omega t}$$

where f is the frequency; $\omega = 2\pi f$, the pulsance, or radian frequency; θ the phase



Alternating current phase relationships.

angle (See figure.); I_0 the amplitude; and I_1 the complex amplitude. In the complex rotation, it is understood that the actual current is the real part of I .

ALTERNATING CURRENT CIRCUIT. An electrical circuit excited by a-c, rather than by d-c. **Reactance** (see **inductance** and **capacitance**) must be considered as well as **resistance**. By using complex-number algebra and the concept of impedance, a-c circuits can be solved like d-c circuits with a generalization of the Ohm law to

$$E = ZI$$

The *actual* instantaneous voltage and current are:

$$e(t) = \text{Re } E = \frac{1}{2} \{E_0 e^{j\omega t} + \tilde{E}_0 e^{-j\omega t}\}$$

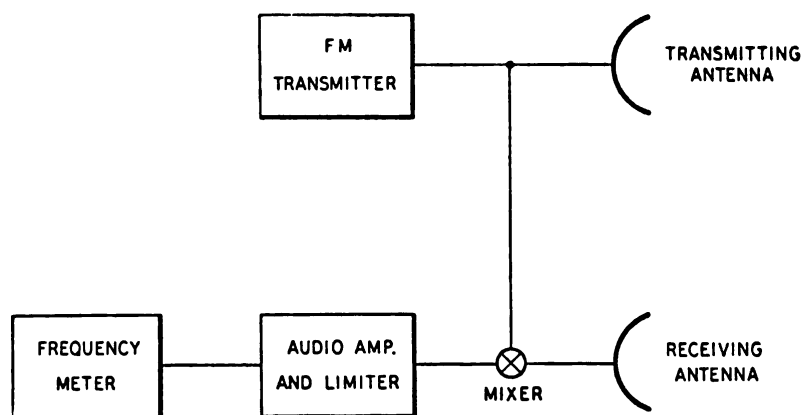
$$i(t) = \text{Re } I = \frac{1}{2} \{I_0 e^{j\omega t} + \tilde{I}_0 e^{-j\omega t}\}$$

where the symbol \sim indicates the complex conjugate.

ALTERNATOR. A device for converting mechanical energy into electrical energy, the

latter appearing as an **alternating current**. The simplest alternating current generator consists of a coil of wire rotating in a constant magnetic field. When the magnet revolves it will carry with it lines of force which will cut the conductor, which is a wire loop embedded in the stationary portion called the armature, and will generate a-c.

atmospheric pressure with altitude, and is called the barometric altimeter. Such instruments must be adjusted for variations in air pressure at the locality, the correction being called the "altimeter setting." Other altimeters are based on radar or radio systems, as, for example, the FM altimeter shown in the figure.



FM altimeter.

This elementary principle must be expanded in several directions if a practical generator of a-c is to be had. First, the rotating part, or rotor, must have magnetic strength in excess of that which could be obtained from a simple permanent magnet. In other words, the poles must be formed by electromagnets whose excitation, in the form of d-c, must be carried to the rotor through slip-ring connections. The rotor is called the field, and the current it uses is called the field current. In high-speed steam-turbine driven alternators as few as two poles are often used, while in slow-speed water-turbine units the number is frequently nearly 100. The stationary part, called the stator, or armature, usually has three sets of overlapping coils, connected in three separate circuits.

ALTIGRAPH. A recording **altimeter**. These instruments are usually pen recorders connected to aneroid barometers (i.e., they are specially calibrated **barographs**).

ALTIMETER. An instrument for indicating altitude above or below a given datum point, usually the ground or sea level. The most common form is based on the variation of

ALTIMETER, ABSOLUTE. An **altimeter** such as a radio altimeter, designed to give acceptably accurate, direct indications of absolute altitude.

ALTIMETER-CALIBRATION STANDARD ATMOSPHERE. An altitude-pressure table computed from the NACA standard **atmosphere**, and used in calibrating aeronautic instruments, such as altimeters.

ALTIMETER, CAPACITANCE. An **altimeter** which determines the height of an aircraft in terms of its **capacitance** to earth.

ALTIMETER SETTING. A number representing the atmospheric pressure at a given place on the surface of the earth, with which the barometric scale of a pressure altimeter is made to conform so that the altimeter will show the approximately correct altitude above that place: the setting of the altimeter to adjust for this pressure.

ALTITUDE. (1) The elevation of an object above a given level, as above the sea or ground, especially as indicated or determined by instrument corrections, or calibrations, and expressed in linear measure. (2) The

vertical distance between any point in the atmosphere or air and a reference point on the earth's surface. (3) In celestial navigation and astronomy, the angular distance of a body from the **celestial horizon** measured vertically on a circle of the **celestial sphere** rising perpendicularly from the observer's horizon.

ALTITUDE, ABSOLUTE. Altitude above the surface of the earth, either land or water. (Cf. **altitude, true.**)

ALTITUDE ALKALOSIS. An alkalosis, a condition of increased alkalinity in the blood and tissues, brought on by exposure to high altitudes.

ALTITUDE BARRIER. (1) The upper limit in the atmosphere beyond which the oxygen supply is insufficient for power plants using oxygen, or the air is too thin to react upon the surfaces of an airplane. (2) The **aero-pause**.

ALTITUDE CIRCLE. Any circle on the **celestial sphere**, parallel to the **celestial horizon** of the observer.

ALTITUDE, CRITICAL. (1) In aircraft terminology, the maximum altitude at which a **supercharger** can maintain a pressure in the intake manifold of an engine equal to that existing during normal operation at rated power and speed at sea level without the supercharger. (2) In guided missile practice, the maximum altitude at which the propulsion system performs satisfactorily.

ALTITUDE DECOMPRESSION SICKNESS. Decompression sickness brought on by flying at high altitudes without benefit of special equipment.

ALTITUDE HYPOXIA. An insufficiency of oxygen in the blood at high altitudes, resulting from a proportional increase of water vapor in the air sacs of the lungs. Usually called "**hypoxia.**"

ALTITUDE, MAXIMUM (FOR ROCKET PROPELLED MISSILES). The maximum altitude attainable by a vertically fired rocket.

ALTITUDE SIGNAL. The radar signal returned to an air vehicle or space ship by the ground or sea surface directly beneath it.

ALTITUDE TETANY. Tetany marked by muscular spasms, especially of the extremities, brought on by exposure to low atmospheric pressure.

ALTITUDE, TRUE. Altitude above mean sea level.

ALTOCUMULUS CLOUD. Billowed cloud of small cumuli (see **cumulus**) which generally form in layers. It is composed of water droplets, although it may lie either above or below the freezing level. It is a middle-level cloud. **Alto**cumulus casts shadows and varies in color from pure white to nearly black. In general **altocumulus** clouds are whitish with darker shadows. "Mackerel sky" is an appropriate description for many **altocumulus** bands.

ALTOSTRATUS CLOUD. A translucent to opaque cloud composed of water droplets through thin layers of which the sun or moon often appear as though seen on a ground-glass screen. It is a middle-level cloud in contrast to the high **cirrus** forms, but may lie either above or below the freezing level. Very frequently, the top part of a layer of **altostratus** is a **cirrus**-type cloud, although this is not observable from below. **Altostratus** clouds cast very little, if any, shadow but usually appear as a dull, drab, grayish sheet. **Altostratus** clouds following **cirrus** and **cirrostratus** is an almost certain indication that a cyclonic disturbance is approaching.

ALUMINUM. Metallic element. Symbol Al. Atomic number 13. Aluminum reacts readily with atmospheric oxygen, forming aluminum oxide. This reaction occurs almost immediately on exposure of the metal to moist air, producing an adherent protective coating over the surface, and thereby preventing further oxidation. Any agent which removes this protective coating tends to destroy the metal.

Many different treatments have been devised to inhibit corrosion of aluminum by producing a thicker and more firmly adherent coating than that resulting from atmospheric oxidation. Aluminum alloys vary in their resistance to corrosion, as well as in other properties.

ALUMINUM ALLOY NUMBERING SYSTEM. Various systems have been devised

for designating the composition and treatment of aluminum alloys by groups of letters and numbers. While usage differs somewhat, the letter "S" following the alloy number indicates that it is a wrought alloy. The letter "O" indicates a fully-annealed alloy, while alloys that have been fully hardened, usually by cold work, carry the letter "H." Intermediate tempers between "O" and "H," are designated as " $\frac{1}{2}$ H," " $\frac{3}{4}$ H," etc. The letter "T" denotes a fully heat-treated alloy. The letter "R" preceding "T" designates rolling (or cold working) after heat treatment. The letters "M" and "X" usually denote experimental alloys. Other letters are sometimes prefixed to alloy designations to indicate modifications of alloys obtained by changes in composition; thus, "A" is a first modification, "B," a second, etc.

ALUMINUM BOROHYDRIDE. A possible rocket fuel, $\text{Al}(\text{BH}_4)_3$. It has a boiling point of 113°F , freezing point -85°F , and a specific gravity of 0.610.

ALUMINUM STEARATE. A gelling material sometimes used with oils to make them semi-solid for use in solid **propellant** combinations.

Am. Americium.

AM. Amplitude Modulation. (See **modulation**, **amplitude**.)

AMA. Air Material Area.

AMALGAM. An alloy containing mercury.

AMATC. Air Material Armament Test Center.

AMATOL. A smokeless high explosive consisting of a mixture of TNT and ammonium nitrate. 60/40 amatol is 60% TNT and 40% ammonium nitrate.

AMBIENT. An adjective used in aerodynamics and thermodynamics to denote "local" or "environmental." It distinguishes measured properties from static ("still") and total values, by denoting that value of the property which occurs within the moving stream as measured by an instrument moving along with it, as contrasted with one held at rest and interrupting the flow.

AMBIENT FUZE. A type of proximity fuze which is not activated as a consequence of actual determination of target presence but by the measurement of a parameter associated with the environment in which the target is normally found.

AMBIENT TEMPERATURE. The temperature of the surrounding medium, such as gas or liquid.

AMERICAN ROCKET SOCIETY. The earliest American organization, founded March 21, 1930, to sponsor rocket research and development. Now a large professional society whose interests encompass all aspects of guided missiles and space flight.

AMC. Air Materiel Command; Wright-Patterson Air Force Base; Dayton, Ohio.

AMERICAN WIRE GAUGE. A system for designating sizes of wiring, which was formerly called the Brown and Sharpe gauge. In this system, wires are numbered in order of decreasing diameter from #0000 (diameter 0.460") to #40 (diameter 0.003144"). In general, an increase of three gauge numbers halves the area and weight per foot, and doubles the d-c resistance.

AMERICIUM. Transuranic radioactive element. Symbol Am. Atomic number 95.

AMINE. An organic chemical compound which may be derived from ammonia by substituting one or more **alkyl** or **aryl** groups for one or more hydrogen atoms of the ammonia (NH_3).

AMMETER. An instrument for measuring electric currents in amperes.

AMMONIA. A chemical compound (NH_3) sometimes proposed as a fuel for liquid propellant rockets. (For its reaction with liquid oxygen, theoretical calculations indicate a specific impulse of approximately 250 lb-sec/lb at a mixture ratio of 1.4:1.)

AMMONIUM NITRATE. The chemical compound, (NH_4NO_3), used as an ingredient in explosives. Its specific gravity is 1.725, melting point $155-166^\circ\text{F}$. It decomposes at 210°F . It is very hygroscopic, insensitive to shock and difficult to detonate.

AMMONIUM PERCHLORATE. A chemical compound (NH_4ClO_4) used as an oxidizing material in solid **propellants**. It has been investigated as a replacement for potassium chlorate in order to obtain a smokeless exhaust, since there is no solid reaction product from this oxidizer. However, one of the reactions products is hydrogen chloride, which is toxic, highly corrosive to metals, and fog-forming. Ammonium perchlorate contains only 34% by weight of oxygen and is thus a less abundant source of oxygen than potassium perchlorate. It is not hygroscopic.

AMMONIUM PICRATE. The ammonium salt of picric acid. Its chemical formula is $\text{C}_6\text{H}_2(\text{NO}_2)_3\text{ONH}_4$. It is a yellowish crystalline material which melts with decomposition at approximately 500°F . It is less sensitive to shock than picric acid, and is frequently used for this reason. It is slightly hygroscopic, and is frequently used in solid propellants. It is also called "Explosive D."

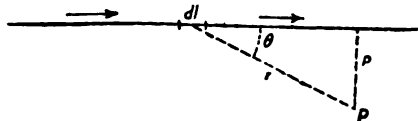
AMORPHOUS. Devoid of regular structure, like glass as distinguished from a crystal.

AMORTISSEUR WINDING. A winding used in electric motors which opposes rotation or pulsation of the magnetic field.

AMPERE. A unit of electrical current, abbrev. as A or amp. (1) The absolute ampere is exactly one-tenth of an abampere, the electromagnetic unit (emu) of current. The absolute ampere has been the legal standard of current since 1950. (2) The International ampere, the legal standard prior to 1950, is the steady current which must flow across a surface in order that one International coulomb of electricity shall pass the surface during each second. $1 \text{ Int. amp} = 0.999835 \text{ Abs. amp}$.

AMPERE-HOUR. A unit of electrical charge, being the amount of electricity represented by a current of one ampere flowing for one hour.

AMPERE LAW. This is a classic law of electromagnetism, useful in discussions of electrodynamics. It has been stated in two apparently distinct forms, which are, however, interconvertible.



One form, sometimes known as the Laplace law, states that the electric current i (**abamperes**), flowing along any line through an element of length dl , gives rise, at a point P distant r (cm) from the element, to a magnetic field of intensity $dH = ipdl/r^3$ (**oersteds**), in which p is the perpendicular distance from P to the line of the element dl ; or $dH = i \sin \theta dl/r^2$, in which θ is the angle between the line of the element and the line joining dl to P . The ultimate basis of the law is, of course, experimental. It may, for example, be deduced indirectly from the Biot-Savart law for the field about an infinitely long, straight wire. Ampere's law furnishes a basis for the solution of all problems relating to the magnetic fields produced by electric currents.

What is sometimes called the circuital form of Ampere's law may be tangibly expressed by saying that if a unit magnetic pole is carried completely around a conductor or system of conductors in which electricity is flowing, in such a way as to oppose the field set up by the currents, the work done, in **ergs**, is 4π times the algebraic sum of the currents, in **abamperes**.

AMPERE RULE. The magnetic flux generated by a current in a wire encircles the current in the counter-clockwise direction, if the current is approaching the observer.

AMPERE TURN. A measure of magnetomotive force.

AMPERITE TUBE. A gas-filled electron tube used to regulate or stabilize the current flow in an electric circuit. In this tube an iron wire is suspended in a hydrogen or helium atmosphere. When current flows through the wire, there is an increase in temperature. Because of the high resistance-temperature coefficient of iron, the total resistance of the circuit increases rapidly under the influence of increasing potential. This operates to stabilize the current in the circuit containing the tube.

AMPLIDYNE. A rotary magnetic or dynamo-electric amplifying device frequently used in servomechanism and control applications because of its high power gain. A single-stage device with a high degree of positive **feedback**.

AMPLIFICATION. A general transmission term used to denote an increase of signal magnitude.

AMPLIFICATION CURRENT. (1) Of an **amplifier**, the ratio of the current produced in the output circuit as a result of the current supplied in the input circuit, to the current supplied to the input circuit. (2) Of a **magnetic amplifier** control-winding, the ratio of the change in output current to the change in current in the control winding required to produce the output current change. Assuming the change from minimum to maximum output current to be 100%, the nominal current amplification will be measured over the following range: An output current 20% greater than the minimum to an output current 20% less than the maximum. Current amplification should be specified for operations of the magnetic amplifier at its rating except for control currents and output currents. The current amplification shall be the minimum that exists for any condition within the rating. (3) Of a **multiplier phototube**, the ratio of the output current to the **photocathode current** due to photoelectric emission at constant electrode voltages. Terms output current and photocathode current as here used do not include **dark current**. This characteristic should be measured at levels of operation that will not cause saturation. (4) Of a **transducer**, the ratio of the magnitude of the current in a specified load impedance connected to a transducer to the magnitude of the current in the input circuit of the transducer. If the input and/or output current consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. By custom, this amplification is often expressed in **decibels** by multiplying its common logarithm by 20.

AMPLIFICATION FACTOR. (1) The ratio between the response of an object flexibly supported by a structure which is subjected to a force applied over a short period of time (e.g., a shock), and the response the object would have if the same force were applied very slowly. Response may be measured in terms of force, load, displacement, acceleration, or other convenient units. Amplification is greatest when the duration of the force applied corresponds to the resonant frequency of the object. (2) Amplification factor is a com-

monly-used parameter in vacuum-tube work and is usually denoted by μ . In the conventional **tube** the current is controlled both by the voltage applied to the **grid** and that applied to the **plate**. Because the grid is closer to the **cathode** from which the **electrons** are drawn, a voltage applied to it is more effective in affecting the electron stream than would be the same voltage applied to the plate (it is the passage of these electrons across the cathode-anode space which constitutes the tube current.) Amplification factor is a measure of the relative effectiveness of voltages on the two electrodes and is defined as the negative of the ratio of the infinitesimal plate voltage change necessary to counteract a given infinitesimal change in grid voltage in order to keep the plate current constant.

$$\mu = - \left. \frac{\partial e_b}{\partial e_c} \right]_{i_b \text{ constant}}$$

where e_b is the plate voltage, i_b is the plate current, and e_c is the grid voltage.

In multielectrode vacuum tubes an amplification factor may be defined for any two electrodes in a manner similar to that done for the plate and grid of the triode.

AMPLIFICATION, MAGNETIC. Amplification achieved by the utilization of the nonlinear properties of saturable magnetic cores. (See **amplifier, magnetic**.)

AMPLIFICATION, POWER. (1) In an amplifier, the ratio of the power level at the output terminals to that at the input terminals.

(2) In a magnetic amplifier, the product of the voltage amplification and the current amplification of that amplifier, using a specified control circuit. (See **amplification, voltage** and **amplification, current**.)

(3) In a transducer the ratio of the power that the transducer delivers to a specified load, under specified operating conditions, to the power absorbed by its input circuit.

If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. This ratio is usually expressed in decibels.

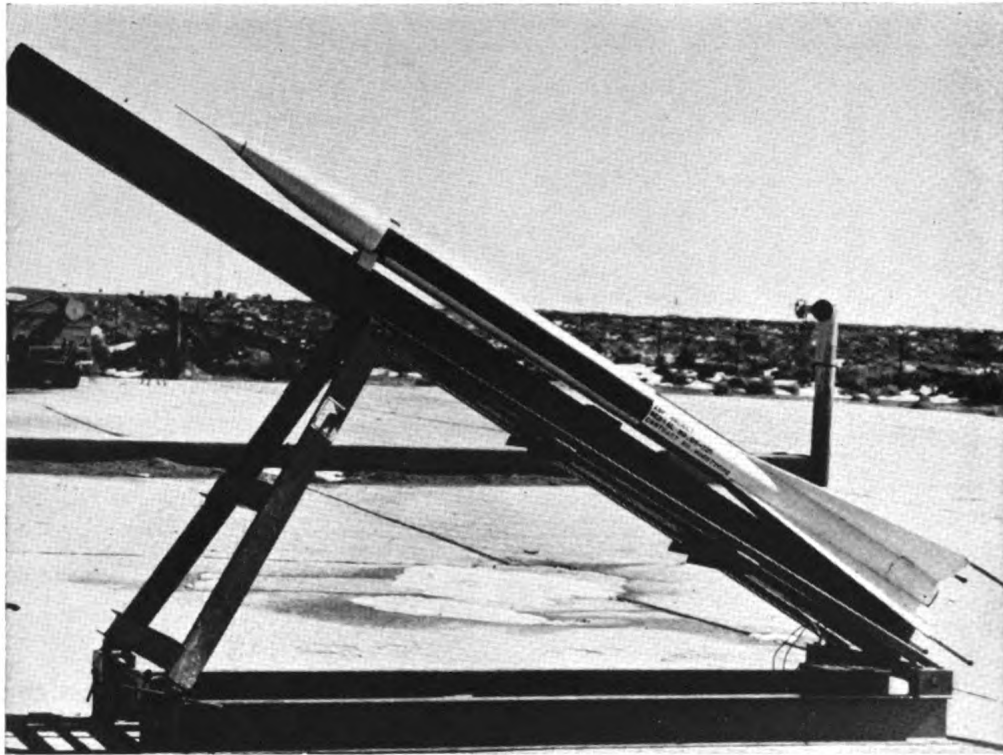
AMPLIFICATION, VOLTAGE. (1) The ratio of the voltage produced at the output terminals of an **amplifier**, as a result of the



Weapon ABLE, being fired from a destroyer in the Caribbean Sea, has been in service with the fleet for several years. Weapon ABLE is a long-range, anti-submarine rocket armed with large amounts of conventional high explosives. (*U.S. Navy Photograph*)

AEROBEE rocket laden with 19 high explosive "firecrackers" launched at Fort Churchill, Canada, to make record weather observations at an altitude of 60 miles. The experiment was conducted for the International Geophysical Year by scientists of the U.S. Army Signal Engineering Laboratories, Fort Monmouth, N.J. August, 1957. (*U.S. Army Photograph*)





ASP (Atmospheric Sounding Projectile) poised in its launcher ready for flight. This rocket was developed for studies of the upper atmosphere by Horning-Cooper Inc. under contract with the Bureau of Ships, U.S. Navy. A system for receiving and recording the scientific data on the ground was also developed in connection with the project. (*U.S. Navy Photograph*)



U.S. Air Force ATLAS intercontinental ballistic missile climbs into the sky from the Air Force Missile Test Center, Cape Canaveral, Florida. First launched successfully in December 1957, the ATLAS was fired in November 1958 for its full 6300-mile missile range; while on December 18, 1958 the final stage of the ATLAS missile, weighing more than 4 tons (launching weight of vehicle about 100 tons) was placed in a satellite orbit about the earth. (*U.S. Air Force Photograph*)

voltage impressed at the input, to the voltage impressed at the input. (2) The ratio of the magnitude of the voltage across a specified load impedance connected to a **transducer**, to the magnitude of the voltage across the input of the transducer. If the input and/or output voltage consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting should be specified. By custom this amplification is often expressed in decibels by multiplying its common logarithm by 20. (3) Of a **magnetic amplifier** control-winding, the ratio of the change in output voltage to the change of voltage across the control winding circuit required to produce the output voltage change. Assuming the change from maximum to minimum output voltage to be 100%, the nominal voltage amplification will be measured over the following range: An output voltage 20% greater than the minimum to an output voltage 20% less than the maximum. Voltage amplification should be specified for operations of the magnetic amplifier at its rating except for control currents and output currents. The voltage amplification should be the minimum that exists for any conditions within the rating.

AMPLIFIER. A device for increasing the magnitude of a quantity. In electronics and electrical engineering, **vacuum tube** amplifiers, **transistor** amplifiers and **magnetic** amplifiers are widely used. The expressions vacuum tube amplifier and transistor amplifier denote the tube or transistor and its associated electrical components which are arranged to reproduce in the output portion of the circuit, in greater magnitude, a voltage or current which is applied to the input of the circuit. This action is usually effected by control of the plate current of the tube or collector current of the transistor by the grid to cathode voltage or base to emitter current, respectively. A change in one of the two last-named variables results in a change in output current (plate or collector current). This change in current develops a change in voltage through a load or output impedance which is also, in general, larger than the input signal voltage which produced it.

AMPLIFIER, AUTOPILOT. An amplifier which receives signals from the outputs of gyroscope reference system and rate gyroscopes, and converts the signals to a form

usable for guidance by the actuator assemblies.

AMPLIFIER, BALANCED (PUSH-PULL). An amplifier circuit in which there are two identical signal branches connected so as to operate in phase opposition and with input and output connections each balanced to ground.

AMPLIFIER, BOOSTER. An amplifier used in audio consoles between mixer controls and the master volume control to prevent deterioration of **signal-to-noise ratio**. It generally supplies sufficient **gain** to compensate for mixing-circuit losses.

AMPLIFIER, BOOTSTRAP. Bootstrap circuit.

AMPLIFIER, BUFFER. An amplifier in which the reaction of output-load-impedance variation on the input circuit is reduced to a minimum for isolation purposes.

AMPLIFIER, CASCADE OR MULTI-STAGE. A chain of amplifier stages in which the output of the first is used as the input of the second, and so on. A stage of such an amplifier is defined as the section from a point just before the grid of one tube to that just before the grid of the next.

AMPLIFIER, CASCODE. A cascade amplifier consisting of a grounded-cathode input stage driving a grounded-grid output stage. Frequently used in television and other UHF and VHF receiver input-stages because of its low **noise figure**. Sometimes referred to as the "Wallman Amplifier" for its originator.

AMPLIFIER, CATHAMPLIFIER. Cathamplifier.

AMPLIFIER, CATHODE-COUPLED. A cascade amplifier (see **amplifier, cascade**) in which the coupling between two stages is obtained by the use of a common cathode resistor.

AMPLIFIER, "CATHODE-FOLLOWER." Amplifier, grounded-plate.

AMPLIFIER, CLASS-A. An amplifier in which the **grid bias** and alternating grid voltages are such that **plate current** in a specific tube flows at all times. To denote that grid current does not flow during any part of the

input cycle, the suffix 1 may be added to the letter or letters of the class identification. The suffix 2 may be used to denote that grid current flows during some part of the cycle. The same notation is used in the Class AB, Class B and Class C amplifiers.

AMPLIFIER, CLASS-AB. An **amplifier** in which the **grid bias** and alternating grid voltages are such that **plate current** in a specific tube flows for appreciably more than half but less than the entire electrical cycle.

AMPLIFIER, CLASS-B. An **amplifier** in which the **grid bias** is approximately equal to the **cutoff value** so that the **plate current** is approximately zero when no exciting grid voltage is applied, and so that plate current in a specific tube flows for approximately one-half of each cycle when an alternating grid voltage is applied.

AMPLIFIER, CLASS-C. An **amplifier** in which the **grid bias** is appreciably beyond the **cutoff** so that the **plate current** in each tube is zero when no alternating grid voltage is applied, and so that plate current flows in a specific tube for appreciably less than one-half of each cycle when an alternating grid voltage is applied.

AMPLIFIER, CONTACT-MODULATED. An **amplifier** for the amplification of d-c and very low frequency signals. The signal source is modulated by a carrier-operated **contact system** (usually 60 or 400 cps), the resulting modulated wave amplified in an a-c amplifier to a suitable level, and subsequently demodulated, sometimes by the same contact system used to accomplish the original modulation.

AMPLIFIER, DIRECT-CURRENT. An **amplifier** capable of amplifying waves of infinitesimal frequency.

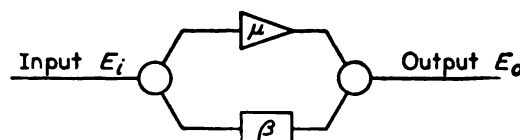
AMPLIFIER, DISTRIBUTED. An **amplifier** consisting of vacuum tubes appropriately distributed along **artificial transmission lines**. This amplifier is capable of much greater band-widths than a conventional amplifier, and the ordinary **figure of merit** or **gain-band width** product does not apply.

AMPLIFIER, DOUBLE-STREAM. A **traveling-wave amplifier** in which the amplification occurs as a result of the interaction of two electron beams having different average veloc-

ities. The amplification takes place in the beam itself and is a result of what might be called "electromechanical interaction."

AMPLIFIER, DYNAMO-ELECTRIC. A power amplifier for d-c and very low frequencies whose output circuit consists of some form of rotating armature in a controllable magnetic field. It is frequently employed in servomechanisms and other control systems.

AMPLIFIER, FEEDBACK. In its simplest form, a feedback amplifier can be regarded as a combination of an ordinary **amplifier** or μ circuit, and a **passive network**, or β circuit, by means of which a portion of the μ circuit



can be returned to its input. The resulting relationship between output and input voltage is

$$E_o = \frac{\mu}{1 - \mu\beta} E_i$$

where $\mu\beta$ is called the feedback factor and can be either plus (positive feedback) or minus (negative feedback), and μ itself is the **amplification factor** of the μ circuit.

AMPLIFIER GAIN. The gain of an amplifier stage is equal to the ratio of the output to the input voltage.

AMPLIFIER, GROUNDED-CATHODE. An electron-tube **amplifier** with the cathode at ground potential at the operating frequency, with input applied between the **control grid** and ground, and the output load connected between plate and ground. (This is the conventional amplifier circuit.)

AMPLIFIER, GROUNDED-GRID. An electron-tube **amplifier** circuit in which the **control grid** is at ground potential at the operating frequency, with input applied between cathode and ground, and output load connected between plate and ground. The grid-to-plate impedance of the tube is in parallel with the load instead of acting as a **feedback** path.

AMPLIFIER, GROUNDED-PLATE (CATHODE FOLLOWER). An electron-tube **am-**

plifier circuit in which the plate is at ground potential at the operating frequency, with input applied between grid and ground, and the output load connected between cathode and ground. A grounded-plate amplifier is characterized by a large negative feedback, and is often used as an impedance-matching device.

AMPLIFIER, HYDRAULIC. A power amplifier (see **amplifier, power**) employed in some servomechanisms and control systems in which power amplification is obtained by the control of the flow of a high pressure liquid by a valve mechanism.

AMPLIFIER, INTERMEDIATE-FREQUENCY. The amplifier used in superheterodyne receivers which amplifies the sum or difference frequency produced in the mixer or first detector by the heterodyning of the signal and oscillator frequencies.

AMPLIFIER, LINEAR POWER. A power amplifier (see **amplifier, power**) in which the signal output voltage is directly proportional to the signal input voltage.

AMPLIFIER, LOGARITHMIC. An amplifier whose output signal is a logarithmic function of the input signal.

AMPLIFIER, MAGNETIC. A device using saturable reactors either alone or in combination with other circuit elements to secure amplification or control.

AMPLIFIER, MAGNETIC, VOLTAGE-CONTROLLED. A magnetic amplifier in which the rate of saturable reactor core flux change during the resetting interval and, consequently the reset flux level are directly related to the signal voltage and are not sensibly affected by such currents as may flow in the control circuit.

AMPLIFIER, MODULATED. An amplifier stage in a transmitter in which the modulating signal is introduced and modulates the carrier.

AMPLIFIER, NON-LINEAR. An amplifier in which the output is not related to the input by a simple constant. One form is the volume-limiting amplifier (see **amplifier, volume limiting**) where the average gain is changed in such a manner that steady-state waveforms are accurately reproduced; another form, fre-

quently called a "clipping or over-driven amplifier," has an output which is a greatly distorted version of the input.

AMPLIFIER, PARAPHASE. An electronic device sometimes used in place of transformers to operate push-pull circuits; essentially a combination amplifier and phase inverter.

AMPLIFIER, PEAK-LIMITING OR GAIN ADJUSTING. Amplifier, volume-limiting.

AMPLIFIER, POWER. An amplifier designed to produce maximum output power rather than maximum voltage gain for a given percent distortion.

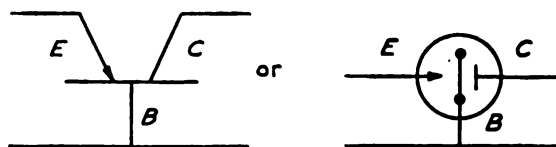
AMPLIFIER, PUSH-PULL. Amplifier, balanced.

AMPLIFIER, REGENERATIVE. An amplifier with positive feedback. (See **amplifier, feedback**.)

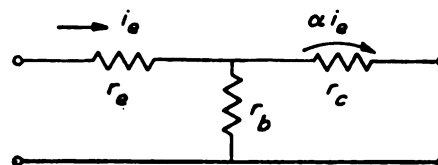
AMPLIFIER, SERVO. The name applied to any amplifier used as a part of a servomechanism.

AMPLIFIER, TRANSISTOR. The transistor may be employed as an amplifier in three basic configurations; the grounded-base, the grounded-emitter, and the grounded-collector.

(1) The grounded-base transistor amplifier has less than unity current amplification (for transistors with $\alpha < 1$); no phase reversal; very low input impedance; and high output impedance.



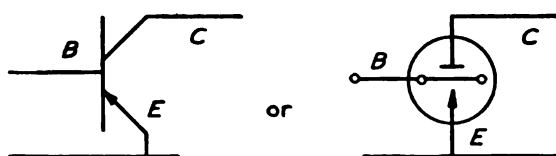
Schematic representation of the grounded-base transistor amplifier



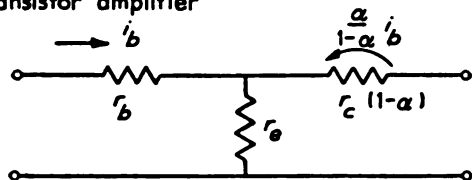
One equivalent circuit of a grounded-base transistor amplifier

(2) The grounded-emitter transistor amplifier has the largest power gain of the three configurations; large current amplification, in-

put impedance relatively low and essentially independent of load; phase reversal.

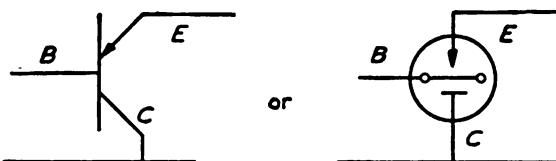


Schematic representation of grounded-emitter transistor amplifier

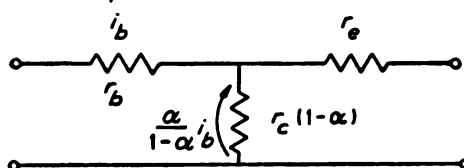


One equivalent circuit of a grounded-emitter transistor amplifier

(3) The grounded-collector transistor amplifier has the lowest power gain of the three configurations; large current amplification; no phase reversal, input impedance quite high but dependent on output impedance; output impedance quite low but dependent on input impedance.



Schematic representation of grounded-collector transistor amplifier



One equivalent circuit of a grounded-collector transistor amplifier

AMPLIFIER, TUNED. An amplifier in which the load impedance consists of, generally, a parallel inductance-capacitance network. The fact that the impedance of this network varies with frequency causes the gain of the amplifier to vary as a function of frequency in a somewhat similar manner.

AMPLIFIER, VACUUM TUBE. An amplifier which has a vacuum tube and its associated circuit arranged to reproduce in its plate

circuit in greater magnitude a voltage or current which is applied in its grid circuit. The term amplifier is used to denote both a single stage or several stages in cascade. Vacuum-tube amplifiers are classified in various ways according to their use, circuit, etc., but all types depend upon a few basic circuits. Thus they may be termed current amplifiers or voltage amplifiers, power amplifiers, audio-frequency amplifiers, radio-frequency amplifiers and various coupling types.

Current amplifiers are designed to give an amplified current in the plate circuit. However, since the vacuum tube is a voltage-controlled device, the input current is applied to the grid as a voltage drop that is produced in an impedance. This voltage drop controls the current in the plate circuit which is designed to give relatively large currents. Voltage amplifiers on the other hand have their plate circuits designed to produce large voltage drops.

In any vacuum-tube amplifier circuit the fundamental operation is the controlling of the plate current by a voltage applied to the grid. This plate-current change is utilized in various ways, giving rise to several standard classifications of voltage amplifiers. Reference to the figures will aid in understanding the

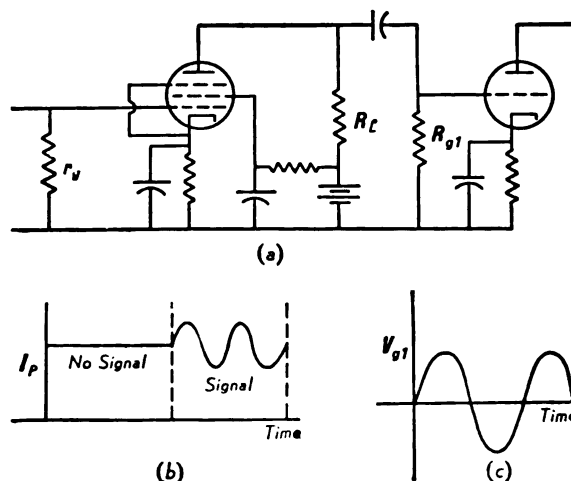


Fig. 1. Resistance coupled vacuum-tube amplifier.

operation. Fig. 1a shows a simple resistance-coupled circuit. The a-c voltage to be amplified is applied across the grid resistor r_g . This voltage alters the plate current which varies as the grid voltage varies. For no-signal voltage on the grid, plate current is a constant value of d-c, but the a-c voltage on the grid

causes this to vary as shown in Fig. 1b. This current produces a potential drop across the plate resistor R_L which has the same form as the current. This voltage is applied across the grid resistor of the following tube through the coupling condenser. However, since a condenser circuit responds only to varying voltages, only the a-c component will appear across the resistor R_{p1} as shown in Fig. 1c. With proper choice of circuit components the voltage on the second grid is several times that impressed on the first grid. The ratio of these voltages is the gain or amplification of the stage.

While this gain varies with frequency, for the middle portion of the operating range it is given by:

$$A = \mu R'_L / (R'_L + R_p)$$

where R_p is the dynamic plate resistance of the tube, μ is the amplification factor of the tube, and R'_L is R_L and R_{p1} in parallel. Pentode tubes are normally used for resistance-coupled amplifiers because of their much greater gain.

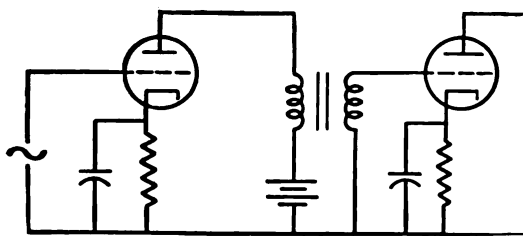


Fig. 2. Transformer coupled vacuum-tube amplifier.

Fig. 2 shows another method, transformer-coupled, of utilizing the current change in the plate circuit. Here the varying plate current produced by the alternating voltage on the grid produces a voltage across the secondary of the transformer. Since the transformer operates only on a-c the voltage across the secondary is a reproduction of that applied to the grid of the first tube. The gain of such a stage is very closely given for the middle of its operating range by:

$$A = \mu n$$

where n is the turns ratio of the transformer (secondary/primary) and μ is the amplification factor of the tube. Because they give a wider frequency range with transformers than other types of tubes, triodes are normally used

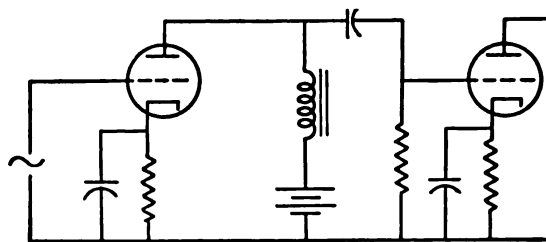


Fig. 3. Impedance coupled vacuum-tube amplifier.

in such circuits. Fig. 3 shows a third method of coupling a voltage amplifier. This is very similar to the resistance-coupled case but the output voltage drop is across a choke or impedance coil. This is an impedance-coupled amplifier. Since the choke causes only a small voltage drop for d-c, very little of the supply voltage is lost and most of it appears at the plate of the tube, thereby increasing the gain by decreasing the dynamic plate resistance of the tube. The frequency response characteristic of this amplifier is usually not as good as for the resistance-coupled type. The gain in the middle range is given by:

$$A = \frac{\mu 2\pi f L}{\sqrt{R_p^2 + (2\pi f L)^2}}$$

where f is the frequency and L is the inductance of the choke in henries. Other symbols are as before.

The three circuits shown are commonly used in audio-frequency amplifiers which must operate over a wide frequency range. For radio-frequency use the range is much more restricted in terms of its proportion of the mid-frequency value. As a consequence such amplifiers can and ordinarily do use tuned circuits for coupling elements. Such an amplifier is shown in Fig. 4. While there are

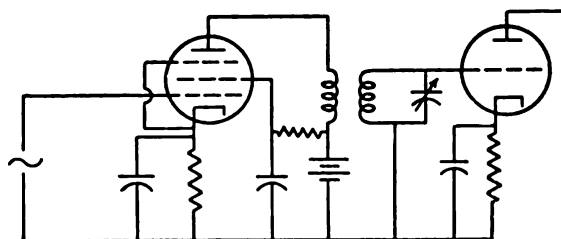


Fig. 4. Tuned vacuum-tube amplifier.

many variations of the tuned amplifier, this is typical of those used in the radio-frequency portion of the usual radio receiver. The response of a tuned amplifier varies markedly

with frequency and the frequency at which the response is a maximum may be adjusted by varying the condenser. This type amplifier, then, serves as a selective device to differentiate between stations and at the same time serves as an amplifier. The condenser shown is the tuning condenser controlled by the dial on the panel of the ordinary radio set.

For amplifying d-c voltages without the introduction of **modulation** a direct-coupled amplifier must be used since the circuits shown before respond only to alternating voltages. Such an amplifier is shown in Fig. 5. It will

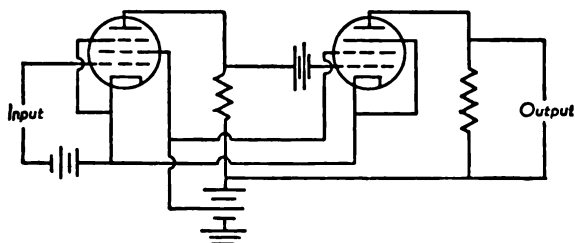


Fig. 5. Direct coupled vacuum-tube amplifier for d-c.

be noted that the high voltage of the plate of the first tube would be applied to the grid of the second if it were not for the bucking action of the grid or C battery which must, therefore, be made large enough to give the correct net voltage on the grid. Unless the A, B, and C voltages are carefully regulated, direct-coupled amplifiers are rather unstable and are to be avoided except in cases where nothing else will serve satisfactorily.

The amplifiers discussed above are intended primarily for voltage amplification. However, in many applications it is necessary to get power from an amplifier unit so at least the final stage is usually adjusted to give power rather than voltage output. An amplifier so adjusted is called a power amplifier. In radio transmitting circuits or large power audio-amplifiers several stages may be power amplifiers. For this type of service the circuit is adjusted to give as large a current as possible through the load, which has much lower resistance than in voltage amplifiers. The tubes used are somewhat larger as a rule than those of voltage circuits and are specially designed for large current outputs. Power amplifiers are frequently classified as Class A, B, AB or C, depending upon just how they are operated. Class A amplifiers operate about a mean grid bias value such that the output wave is essen-

tially the same as the input wave and the d-c plate current has a constant value (the voltage amplifiers are Class A). A Class B amplifier has the grid bias adjusted so that plate current flows only on the positive half-cycle of the input signal. Class AB is intermediate between A and B. In these three classes a subscript 1 is often used to denote that the grid does not take current, and a subscript 2 to denote that grid current flows. Since AB and B amplifiers using single tubes do not give output waves similar to the input waves they must be operated **push-pull** for audio-frequency work. Class C amplifiers are adjusted so plate current flows for less than a half-cycle of the input signal. They are used exclusively for radio-frequency work where a tuned circuit may be used for the load. (See **tank circuit**.) Fig. 6 indicates the relative bias values for the different types of service.

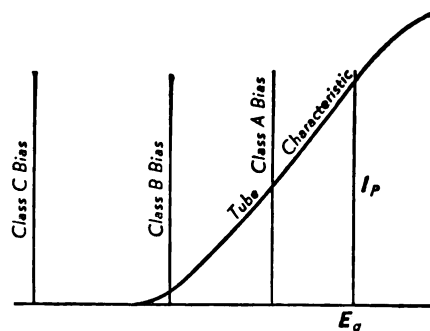


Fig. 6. Bias adjustments for various vacuum-tube amplifier classes.

The efficiency becomes better but the distortion worse in the order A, AB, B and C. For audio-frequency work the power amplifiers are normally connected to the load (**loud-speaker**) through a transformer, while in radio-frequency work air-cored transformers and capacitance coupling are common.

AMPLIFIER, VIDEO-FREQUENCY. A device capable of amplifying such signals as comprise periodic visual presentation.

AMPLIFIER, VOLUME-LIMITING. An amplifier containing an automatic device which functions when the input volume exceeds a predetermined level, and so reduces the **gain** that the output volume is thereafter maintained substantially constant, notwithstanding further increase in the input volume. The normal gain of the amplifier is restored

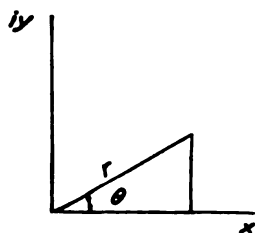
when the input volume returns below the predetermined limiting level.

AMPLIFIER, VOLTAGE. An amplifier designed for the primary purpose of producing an increase in signal voltage with little or no attention to the available output power of the stage.

AMPLIFIER, WIDE-BAND. An amplifier having uniform response over many decades of frequency. One example is the video amplifier. (See **amplifier, video-frequency**.)

AMPLITRON. A trade name of the Raytheon Manufacturing Company for an electron tube developed under a U.S. Army Signal Corps Engineering Laboratory contract. This tube develops exceptional peak powers and is able to boost basic magnetron signals as much as 8-14 times. It combines high power with wide frequency range and thus has special applications in frequency-modulated radar sets which have a moving target indicator capability.

AMPLITUDE. (1) If a complex number is represented in polar coordinates it becomes $r(\cos \theta + i \sin \theta)$ and the angle θ is the ampli-



tude, argument, or phase of the number. (See **de Moivre theorem**.) The term is also used to designate a parameter occurring in elliptic functions and integrals. (2) The crest or maximum value of a periodic (or specifically a simple harmonic function of space or time) or, more generally, any parameter that when changed, merely represents a change in scale factor. (3) In electronics, a measure of the maximum signal, positive or negative, from the average of the quiescent value. (4) In amplitude-modulation systems, this quantity becomes a function of time, and its instantaneous value is of importance, but it is still referred to as the amplitude.

AMPLITUDE, ACCELERATION. Amplitude expressed in terms of the acceleration in-

herent in the change of direction of motion of a particle vibrating at a given amplitude and frequency. For a sinusoidal motion, this relation is shown by the expression:

$$a = A(2\pi)^2 f^2$$

where a is the acceleration in distance-time units, A is the amplitude in linear units and, f is the frequency in cycles per second. Dividing both sides of the equation by the acceleration of gravity, the acceleration in g 's is approximated by:

$$G = 0.1 \frac{A}{2} f^2$$

AMPLITUDE COMPARISON. The process of indicating the time at which two waveforms reach the same **amplitude**. It may also be considered to be the method of determining the abscissa of a waveform, given its ordinate.

AMPLITUDE DISCRIMINATOR. A circuit which performs an **amplitude comparison**. In addition, the sense and magnitude of the inequality of the amplitudes may be obtained.

AMPLITUDE DISTORTION. A type of **distortion** that occurs in an **amplifier** or other device when the amplitude of the output is not exactly a linear function of the input amplitude.

AMPLITUDE, DOUBLE. Amplitude, peak-to-peak.

AMPLITUDE-FREQUENCY DISTORTION. Distortion due to an undesired amplitude-frequency characteristic. The usual desired characteristic is flat over the frequency range of interest. Amplitude-frequency distortion is sometimes called "amplitude distortion" or "frequency distortion."

AMPLITUDE, INITIAL. The maximum displacement from a reference point of a periodic function. The periodic function can describe the motion of a pendulum point, the motion of a point on a spring or of a point on a mechanical system which is performing oscillatory motion or may represent the motion of a wave in a medium. (Cf. **harmonic motion**.)

AMPLITUDE MODULATION, OR AM. Modulation in which the **amplitude** of a wave is the characteristic subject to variation.

AMPLITUDE-MODULATED TRANSMITTER. Transmitter, amplitude-modulated.

AMPLITUDE OF OSCILLATION. The peak value of a sine wave is called its "amplitude." By extension, a nearly sinusoidal wave, such as a damped-sine wave, or a slowly amplitude modulated wave, written in the form

$$x = F(t) \sin(\omega t + \phi)$$

is said to have the (time-varying) amplitude $F(t)$.

AMPLITUDE, PEAK-TO-PEAK. Of an oscillating quantity, the difference between extremes of the quantity; or the algebraic difference of the positive and negative magnitudes of maximum deviation from the rest condition: also termed **double amplitude**.

AMPLITUDE SELECTION. Clipper circuit.

AMPLITUDE VERSUS FREQUENCY RESPONSE CHARACTERISTIC. The variation with frequency of the gain or loss of a device or a system.

AMR. Atlantic Missile Range.

AMRI. Association of Missile and Rocket Industries.

ANABATIC WIND. A wind blowing uphill. In general, anabatic winds are winds originating from surface heating, such as a breeze blowing up a valley when the sun warms the ground.

ANALOG. The representation of one system in terms of the characteristics of another, e.g., electrical circuits used to represent mechanical or acoustical systems.

MECHANICAL FUNCTIONS AND ELECTRICAL ANALOGS

Mechanics	Electric Analog
Where	Where
s = distance	Q = quantity
m = mass	L = inductance
t = time	t = time
k = elastic constant	C = capacitance
p = period of vibration	p = period of oscillation

Mean velocity, $V = \frac{s}{t}$ Current, $I = \frac{Q}{t}$

Instantaneous velocity, $v = \frac{ds}{dt}$ $i = \frac{dq}{dt}$

Acceleration, $a = \frac{v - v_0}{t} = \frac{dv}{dt}$

when $V_0 = 0$ $v = at$
 $s = \frac{1}{2} at^2$

Momentum = mv

Force, $F = \frac{mv - mv_0}{t} = ma = m \frac{dv}{dt}$

Electromotive force, $E = \frac{LI - LI_0}{t} = L \frac{di}{dt}$

Weight (force of gravity) = mg

Centrifugal force = $\frac{mv^2}{r}$

where r = radius of path

Work (Energy), $W = Fs = mas$
 $= \frac{1}{2}mv^2$
 $W = EQ = EIt$
 $= \frac{1}{2}LI^2$

Power, $P = \frac{W}{t} = FV$ $P = EI$

Displacement of spring, $s = Fk$	Capacitor charge, $Q = EC$
Period of vibration, $p = 2\pi\sqrt{km}$	Period of oscillation, $p = 2\pi\sqrt{CL}$

AMTI. Airborne Moving Target Indicator.

AN. Army-Navy.

AN SYSTEM OF NOMENCLATURE FOR ELECTRONIC EQUIPMENT. The U.S. Army-Navy numbering system. An example of the AN numbering system is the familiar designation for a surveillance radar in wide use by the antiaircraft artillery—*AN/TPS-1D*. The first two letters *AN* designate "Army-Navy" (tacitly including Air Force). The third letter denotes the type of installation for the equipment (*T* means "transportable"). The fourth letter indicates the type of equipment (*P* is radar). The fifth letter indicates the purpose of the equipment (*S* stands for "surveillance"). The final number refers to the model number and any letters following it indicate modifications to that model. The general nomenclature is given in the following table.

ARMY-NAVY ELECTRONIC EQUIPMENT NOMENCLATURE

INSTALLATION	TYPE OF EQUIPMENT	PURPOSE
<i>A</i> —airborne	<i>A</i> —invisible light, heat radiation	<i>A</i> —auxiliary assemblies (not complete operating sets)
<i>B</i> —underwater, mobile, submarine	<i>B</i> —pigeon	<i>B</i> —bombing
<i>C</i> —air transportable	<i>C</i> —carrier (wire)	<i>C</i> —communications (receiving and transmitting)
<i>D</i> —pilotless carrier	<i>D</i> —radiac	<i>D</i> —direction finder
<i>F</i> —fixed	<i>E</i> —nupac	<i>G</i> —fire control (gun directing or searchlight directing).
<i>G</i> —ground, general ground use	<i>F</i> —photographic	<i>H</i> —recording (photographic, meteorological and sound).
<i>K</i> —amphibious	<i>G</i> —telegraph or teletype	<i>L</i> —searchlight control (term no longer used, use "G").
<i>M</i> —ground, mobile (installed as operating unit in a vehicle which has no function other than transporting the equipment.	<i>I</i> —interphone and public address	<i>M</i> —maintenance and test assemblies (including tools)
<i>P</i> —pack or portable (animal or man)	<i>K</i> —telemetering	<i>N</i> —navigational aids (including altimeters, beacons, compasses, racons, depth sounding, approach and landing)
<i>S</i> —water surface craft	<i>L</i> —countermeasures	<i>P</i> —reproducing (photographic and sound)
<i>T</i> —ground, transportable	<i>M</i> —meteorological	<i>Q</i> —special or combination of purposes
<i>U</i> —general utility (includes two or more general installation classes, airborne, shipboard and ground)	<i>N</i> —sound in air	<i>R</i> —receiving, passive detecting
	<i>P</i> —radar	<i>S</i> —detecting and/or range and bearing
	<i>Q</i> —sonar and underwater sound	<i>T</i> —transmitting
<i>V</i> —ground, vehicular (installed in vehicle assigned for functions other than carrying electronic equipment, such as tanks).	<i>R</i> —radio	<i>W</i> —remote control
<i>W</i> —underwater, fixed	<i>S</i> —special types, magnetic, etc., or combinations of types.	<i>X</i> —identification and recognition
	<i>T</i> —telephone (wire)	
	<i>V</i> —visual and visible light	
	<i>X</i> —facsimile or television	

Modifications of numerical types are designated by a terminal letter beginning with A and increasing through the alphabet. In such instances detail parts and subassemblies are

not interchangeable with other models, but the component itself is interchangeable physically, electrically, or mechanically, or certainly functionally.

ANALOG COMPUTER. An electronic calculating machine in which quantities and relationships are represented by continuously variable physical quantities such that approximate solutions can be obtained readily. (At present, the analog computing system is the principal device used for simulation of dynamic problems in the study of the control loop and system performance associated with a missile's ability to respond to received signals.) In an analog computer, quantities are represented without explicit use of language.

ANALYZER. (1) The **nicol prism** (or other device which passes only that component of light which is polarized in a particular plane) which is placed in the **eyepiece** of a **polariscope** or similar instrument. (2) A volt-ohm-milliammeter test instrument.

ANALYZER, FREQUENCY. An electronic test equipment with which the frequency content of a complex electrical signal can be ascertained, usually in terms of a Fourier series.

ANASTIGMAT. A compound lens combination corrected so that both **astigmatism** and the **curvature of the field** are largely eliminated over a considerable area in the image plane.

ANC. Army-Navy-Commercial.

ANCILLARY EQUIPMENT. An equipment of a **guided missile** not directly employed in its operation, but necessary for logistic support, preparation for flight or assessment of target damage; e.g., test equipment, vehicle transport.

"AND" CIRCUIT. Computer.

ANDROMEDA. The brighter stars of this constellation make an almost straight line between the constellations of **Perseus** and **Pegasus**. The most famous feature of the constellation is the great **nebula**. This is the only **spiral** which is actually visible to the naked eye and may be distinguished as a faint blur against a moonless sky close to the faintest star in the constellation which appears on the map (Page 150). This is the largest of the spirals and is distant from the earth about 800,000 light years.

The bright star in Andromeda closest on the map to Perseus was called Almach by the Arabs and is a **double star**, one of the most

beautiful in the sky in a small telescope. One component is a brilliant orange and the other a striking emerald color. Careful examination in a large telescope shows the green component to be also a double star.

ANECCHOIC ROOM. A room in which sound reflections from the boundary surfaces have been reduced to a negligible amount.

ANELASTICITY (INTERNAL FRICTION). In general, any deviation from the ideal behavior postulated by classical elasticity theory (where the strain is proportional to the applied stress and follows instantaneously upon its application). The term is applied particularly to those phenomena associated with the damping of elastic waves in solids. Numerous causes are known for these effects, such as thermal diffusion, motion of grain boundaries, diffusion of twin boundaries, atomic solution diffusion, etc. The damping associated with a given process depends strongly on the frequency of the elastic wave.

ANEMOGRAPH. A recording **anemometer**.

ANEMOMETER. An instrument for indicating the direction and velocity of the air (or other gases). The most common type is the *Robinson Cup Anemometer*, which consists of three or four hemispherical cups attached to horizontal cross arms so that the wind revolves them on a vertical axis through which they actuate a recording device. The *plate anemometer* consists of a simple plate mounted in such a manner that the wind blows against it, deflecting it in the direction toward which the wind is blowing. A pointer or scale mounted along the plate measures the deflection of the plate, which can be correlated with the wind velocity. The *pressure-tube anemometer* is actuated by difference in static and dynamic pressure in an air-stream flowing across a tube mounted with its opening directly into the stream.

ANEMOSCOPE. An instrument actuated by a wind vane, and showing wind direction on a calibrated scale.

ANEROID. Without air.

ANEROID BAROMETER. Barometer, aneroid.

"ANGELS." Radar reflections in the lower atmosphere, usually of short duration, and

observed most frequently below 3000 feet. In many cases, these reflections are due to insects or birds.

ANGLE. The figure obtained by drawing two straight lines from a point. In trigonometry, an angle measures the rotation of one straight line, the terminal line, about a fixed point on an initial line. It is positive if the direction of rotation is counterclockwise. If the magnitude of the angle equals 2π radians, it is called a perigon angle and such an angle, divided into 360 equal parts, has a magnitude of 360 degrees (360°). A right angle equals 90° or $\pi/2$ radians; a straight angle, 180° or π radians; an acute angle is less than 90° ; an obtuse angle, greater than 90° (but frequently limited to one less than 180°).

ANGLE, AILERON. The angular displacement of an aileron from its neutral position. It is positive when the trailing edge of the right aileron is below the neutral position.

ANGLE, CRAB. The angle between the direction in which an air vehicle is heading and its true course.

ANGLE, DEPRESSION. The angle measured downward from the horizontal to the axis of an airborne radar beam directed at a target. This is the complement of the **incidence angle** of the beam at the target plane.

ANGLE, DIFFRACTION. The angle between the direction of an incident beam of light and any resulting diffracted beam. (See **diffraction**.)

ANGLE, DIHEDRAL. The angle between two planes. The dihedral angle is zero if the planes are parallel. If the direction cosines of perpendiculars to two planes are λ, μ, ν and λ', μ', ν' the dihedral angle between the planes is given by

$$\cos \theta = \lambda\lambda' + \mu\mu' + \nu\nu'$$

ANGLE, DRIFT. The horizontal angle between the longitudinal axis of an air-vehicle, missile or space ship and its path relative to the ground.

ANGLE, ELEVATOR. The angular displacement of the elevator from its neutral position. It is positive when the trailing edge of the elevator is below the neutral position.

ANGLE, FLIGHT-PATH. The angle between the flight path of the air-vehicle and the horizontal.

ANGLE, GLIDING. The angle between the flight path during a glide and a horizontal axis fixed relative to the earth.

ANGLE MODULATION. Modulation in which the angle of (the vector generator) a sine-wave carrier is the characteristic subject to variation. *Phase* and *frequency modulation* are forms of angle modulation.

ANGLE OF ARRIVAL. The angle between the line of propagation of a radiowave and the earth's surface at the point of reception.

ANGLE OF ATTACK. (1) The acute angle between the airstream and a reference chord of the **airfoil**. There are two such chords: the one employed for general and structural use is the geometric chord; the other is the mean aerodynamic chord. (2) The angle between the wind direction and some reference line fixed with respect to the airframe, usually the longitudinal axis. (3) The angle between the longitudinal axis of a missile and the instantaneous tangent of the trajectory.

Absolute angle of attack is measured from the attitude of zero lift. *Critical angle of attack* is that angle beyond which the flow pattern about the body causes disturbing effects in aerodynamic forces of lift and drag. *Angle-of-attack pitch* is the angle between the wind and the **pitch** plane, positive upward. *Angle-of-attack yaw* is the angle between the wind and the **yaw** axis. *Angle-of-attack for infinite aspect ratio* is the angle of attack at which an airfoil produces a given **lift coefficient** in a two-dimensional flow. It is also called "effective angle of attack." *Induced angle of attack* is the difference between the actual angle of attack and the angle of attack for infinite aspect ratio of an airfoil for the same lift coefficient.

ANGLE OF BEAM. In a directional antenna system, the angle which encloses the greater part of the transmitted or received energy. (See **beam width**.)

ANGLE OF DEFLECTION. In cathode-ray devices, the angle through which the beam is deflected.

ANGLE OF DEPARTURE. (1) The angle formed by the tangent to the trajectory of a

missile at propulsion cut-off, and the horizontal (i.e., earth's horizontal plane projected upward to the cut-off point). It is denoted by ϕ_B . (2) The angle between the line of propagation of a radiowave and the earth's surface at the point of transmission.

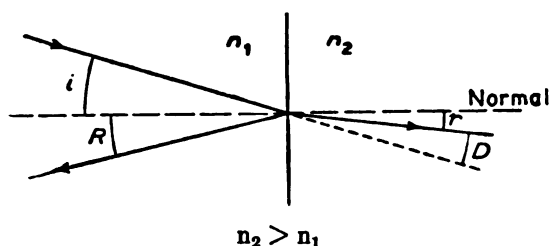
ANGLE OF DEVIATION. The angular change in direction of a ray of light, or other electromagnetic radiation, upon entering another medium. (See **angle of incidence**.)

ANGLE OF DIP. Dip-needle.

ANGLE OF ELEVATION. The acute vertical angle between a horizontal line and an ascending line, such as a line from an observer to an elevated object.

ANGLE OF FIRE. An indication of antenna direction.

ANGLE OF INCIDENCE. (1) The angle at which an airfoil is set with respect to the air-frame longitudinal axis. It is the angle at which an airfoil surface is attached to an air-frame. This angle is sometimes called "wing setting." (2) The angle between a ray of light striking a surface and the normal to that surface, as shown in the accompanying figure,



where i is the angle of incidence, R is the angle of reflection, r is the angle of refraction, D is the angle of deviation, n_1 is the index of refraction of the medium from which the light is incident upon the surface, and n_2 is the index of refraction of the medium into which the light is refracted from the surface. (See the **Snell Law**.)

ANGLE OF ORIENTATION. Orientation angle.

ANGLE OF PITCH. The acute angle between two planes defined as follows: One plane includes the lateral axis of the relative wind; the other plane includes the lateral axis and the longitudinal axis of an air vehicle.

The angle is positive when the nose of the air vehicle is above the direction of the relative wind. In normal flight the angle of pitch is the angle between the longitudinal axis and the direction of the relative wind.)

ANGLE OF REFLECTION. The angle between a ray of light and the normal to a surface. This angle and the **angle of incidence** are in the same plane. They are related by the equality $R = i$.

ANGLE OF REFRACTION. The angle between a ray of light after **refraction** at an interface between two media and the normal to the interface. This angle and the **angle of incidence** are in the same plane.

ANGLE OF ROLL. The angle that an air-vehicle makes with a chosen reference plane in rolling; usually, the angle between the **lateral axis** and a horizontal plane. The angle of roll is considered positive if the roll is to starboard (the right-hand side facing forward).

ANGLE OF SIDESLIP. The angle, as seen from above, between the longitudinal body axis of an air vehicle and the direction of the undisturbed airflow past the vehicle. This angle is positive when the forward end of the longitudinal axis points to port. (See **angle of yaw**.)

ANGLE OF YAW. The angle, as seen from above, between the longitudinal body axis of an air vehicle and a chosen reference direction. This angle is positive when the forward end of the longitudinal axis points to starboard.

The reference direction for measuring the angle of yaw is often the direction of the airflow past the body, making the angle of yaw equal to the angle of sideslip, though opposite in sign; under certain conditions, however, as in turning, another reference direction is used.

ANGLE OR PHASE OF SINE WAVE. The measure of the progression of the wave in time or space from a chosen instant or position. In the expression for a sine wave, the angle or phase is the value of the entire linear function. In the representation of a sine wave by a rotating vector, the angle or phase is the angle through which the vector has progressed.

ANGLE, RUDDER. The acute angle between the rudder and the plane of symmetry of an air vehicle. It is positive when the trailing edge has moved to the left looking forward.

ANGLE, SOLID. Consider a small cone with a base of area dS and a vertex at a fixed point P . This cone will cut out an area $d\sigma$ on a sphere of radius r with center at P . The **solid angle** subtended by dS at P is defined as $d\omega = d\sigma/r^2$. It is numerically equal to the area cut out by the same cone on a sphere of unit radius at the same point P . The unit used for measuring a solid angle is the **steradian**.

ANGLE, ZERO-LIFT. The angle of attack of an airfoil when its lift is zero.

ANGSTROM UNIT (Å). A unit of length equal to one ten-thousandth of a micron, or one hundred millionth of a centimeter. It is used to measure and express the length of extremely short waves, and atomic dimensions.

ANGULAR ACCELERATION. Acceleration, angular.

ANGULAR ALTITUDE. A measure in degrees of a given object above the horizon, taken from a given or assumed point of observation, and expressed by the angle between the horizontal and the observer's line of sight.

ANGULAR FREQUENCY. Frequency, angular.

ANGULAR MOMENTUM. The product of the **moment of inertia** of a rotating body or system of bodies, as measured about any axis of rotation, by the angular velocity about that axis. Angular momentum is a **conserved quantity**, which remains constant in any isolated system. It is a **vector** quantity, having the direction of the axis of rotation and a sense such that the vector points toward the observer if the rotation is counterclockwise as seen by him. (See also **torque**.)

ANGULAR THRUST MISALIGNMENT. The angle between the axis of a rocket and the axis of the thrust, when the line of action of the thrust passes through the center of mass, but is not parallel to the axis of the rocket. (See also **linear thrust misalignment**.)

ANGULAR VELOCITY. Velocity, angular.

ANILINE. The organic compound $C_6H_5NH_2$, a liquid boiling at $184^\circ C$., and freezing at $-8^\circ C$., which is used as a rocket **propellant**. The high freezing point of aniline is often reduced by the addition of furfuryl alcohol, which itself is a moderately good rocket fuel, especially with nitric acid as an oxidant.

ANION. (1) An ion which deposits on the anode. (2) A negatively-charged ion. (3) That portion of an electrolyte which carries the negative charge and travels against the conventional direction of the electric current in a cell.

ANISOELASTIC. Nonisoelastic.

ANISOTROPIC. Nonisotropic, and thus having different optical or other physical properties in differing directions. Wood and calcite crystals are anisotropic, while fully-annealed glass and, in general, fluids at rest are isotropic.

ANNEALING. The process of holding a solid material at an elevated temperature for some length of time in order that any metastable condition (e.g., frozen-in **strains**, **dislocations**, **vacancies**, etc.) may go into thermodynamic equilibrium. This may result in **recrystallization** and **polygonization** of cold-worked samples.

ANNIHILATION. (1) A process in which a pair of anti-particles meet and convert spontaneously into one or more photons; it is the inverse of **pair production**. The commonest example is the annihilation of an electron and a positron, the rest masses of which are converted into (usually) two 0.511-mev photons according to the principle of **mass-energy equivalence**. (2) The conversion of rest mass into electromagnetic radiation.

ANNIHILATION FORCE. Contribution to the force between an electron and a positron arising from the fact that these particles may virtually annihilate each other, thereby making the charges less effective and the attraction less. This raises the 1^3S level of **positronium** by an amount $\frac{1}{4}\alpha^4 mc^2$ ($\alpha = \frac{1}{137}$).

ANNIHILATION RADIATION. Electromagnetic radiation produced by the union, and consequent **annihilation**, of a positron and

an **electron**. Each such annihilation usually produces two, rarely one or three, photons. These photons have properties identical with those of γ -rays, and accompany the decay of all positron-emitting radioactive substances. A positron and an electron are most likely to unite when their relative velocity is small; hence the energy available for the annihilation radiation will be that of two rest-masses of the electron, $2m_e c^2$ [= 1.02 mev], and the process will usually result in the production of two oppositely-directed photons, each of energy 0.511 mev.

ANODE. The electrode by which current enters a device (in contradistinction to an electron flow). The anode is the positive terminal of an electroplating cell, but the negative terminal of a battery. The term anode is customarily used for any thermionic tube electrode operated at an appreciably-positive potential. Thus the plate, i.e., the thermionic tube electrode to which the main current flows, is an anode.

ANODE BREAKDOWN VOLTAGE (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). The anode voltage required to cause conduction across the main gap, with the starter gap not conducting, and with all other tube elements held at cathode potential before breakdown.

ANODE CURRENT. Electrode current.

ANODIZE. To place a protective film on a metal surface by electrolytic or chemical action. Aluminum and magnesium parts of electronic equipment are frequently anodized.

ANOTRON. A trade name for a type of vacuum tube rectifier which has a copper anode and a relatively large cathode made of sodium or other substance which emits a cold cathode glow discharge when current is passing through it.

ANOXIA. (1) Literally, the absence of oxygen in the blood, cells, or tissues, as would be the case if a person were at an altitude of 50,000 feet or above without benefit of oxygen equipment. (2) **Hypoxia**.

ANTENNA. In the process of radio communication the power generated in the **transmitter** must be projected or radiated into space and at the **receiver** some of this radiated

energy must be abstracted from the passing radio wave and fed into the receiver proper. It is the antenna which radiates the power at the transmitter and which picks up the signal at the receiver. The antenna form ranges from a simple short length of wire for the receiver to an elaborate array of wires or steel towers for large transmitters. When alternating voltage of a high frequency is connected to a conductor which is open at the end a corresponding high-frequency a-c will flow in the conductor and return to the voltage source through the capacitance between the conductor and the rest of the circuit. This rapid a-c causes energy to be radiated into space from the conductor. This energy travels out from the conductor and does not return. The conductor in this case is the antenna (of course the various connecting wires of the transmitter also have high-frequency a-c and hence will radiate to some extent but very inefficiently). The efficiency with which an antenna radiates is determined by its length and configuration, and its location with respect to the ground, surrounding objects, etc. In general, better radiation is obtained when the antenna length is an appreciable part of a wavelength of the radio signal. Thus they are usually such values as quarter-wave, half-wave, etc.

ANTENNA, ACROMATIC. An **antenna** whose characteristics are uniform over some desired band of frequencies.

ANTENNA, ADCOCK. A pair of vertical **antennas** separated by a distance of one-half wavelength or less, and connected in phase opposition to produce a radiation pattern having the shape of a figure of eight.

ANTENNA, APERIODIC. A non-resonant, and thus frequency-insensitive **antenna**.

ANTENNA ARRAY. Two or more **antennas** coupled together.

ANTENNA ARRAY, APERTURE OF THE. That portion of a plane surface near the **antenna**, perpendicular to the maximum direction of radiation, through which the major portion of the radiation passes.

ANTENNA ARRAY, BINOMIAL. A type of broadside array in which the radiation pattern will contain a single lobe (or two lobes if the pattern is bidirectional). All of the antennas

are fed in the same phase, they are uniformly spaced at half-wavelength intervals, and the relative current amplitudes in various elements in the array follow the numbers of the binomial expansion. (See **antenna array, broadside**.)

ANTENNA ARRAY, BROADSIDE. An **antenna array** whose direction of maximum radiation is perpendicular to the line or plane of the array according to whether the elements lie on a line or a plane. A *uniform broadside array* is a linear array whose elements contribute fields of equal amplitude and phase.

ANTENNA ARRAY, CLOSE-SPACED. An **antenna array** in which the spacing of the elements is less than $\frac{1}{2}$ wavelength.

ANTENNA ARRAY, CONTINUOUS LINEAR. An infinite number of infinitesimally spaced sources. Some dielectric antennas (see **antenna, dielectric**) and leaky-pipe antennas (see **antenna, leaky-pipe**) belong to this general class.

ANTENNA ARRAY, END-FIRE. A linear antenna array whose direction of maximum radiation is along its axis.

ANTENNA ARRAY, LINEAR. An **antenna array** whose elements are equally spaced along a straight line.

ANTENNA, BANDWIDTH OF. The range of frequencies within which the performance of an antenna, in respect to a given characteristic, conforms to a specified standard.

ANTENNA BEAM. The principal lobe of an antenna pattern. An antenna beam may have many forms such as "pencil beam," "conical beam," "toroidal beam" or "omnidirectional beam."

ANTENNA, BEVERAGE. **Antenna, wave.**

ANTENNA, BICONICAL. An **antenna** formed by two conical conductors, having a common axis and vertex, and excited at the vertex. When the vertex angle of one of the cones is 180° , the antenna is called a **discone**.

ANTENNA, BROADBAND. An **antenna** which will function satisfactorily over a bandwidth in the order of 10 per cent or more of its center frequency.

ANTENNA, "BUPS." A 10 cm dipole **antenna array** which is non-directional in azimuth. Maximum radiation occurs at low vertical angles. Used for beacon service.

ANTENNA, CAGE. An **antenna** in which the radiating members are parallel rods arranged in a cylindrical fashion.

ANTENNA, CAPACITOR. An **antenna** in which the capacitance between two conductors or systems of conductors is the essential characteristic. A dielectric antenna. (See **antenna, dielectric**.)

ANTENNA, CHEESE. A cylindrical parabolic reflector enclosed by two plates perpendicular to the cylinder, so spaced as to permit the propagation of more than one mode in the desired direction of polarization. It is fed on the focal line. It is used in radar applications on ships to avoid losing targets when the ship rolls or pitches.

ANTENNA, CIRCULAR. Essentially a folded dipole antenna (see **antenna, folded dipole**) bent into a circle.

ANTENNA, "CLOVERLEAF." An **antenna** for transmission or reception of horizontally-polarized radiation in a non-directional pattern in a plane normal to the axis of the antenna. Its name arises from the fact that it is comprised of a cluster of four half-wave, curved, radiating elements arranged in the pattern of a four-leaf clover.

ANTENNA, COAXIAL. An **antenna** comprised of a quarter wavelength extension to the inner conductor of a **coaxial line**, and a radiating sleeve which, in effect, is formed by folding back the outer conductor of the coaxial line for approximately one-quarter wavelength.

ANTENNA(S), COLINEAR COAXIAL. Coaxial antennas arranged in a colinear array.

ANTENNA, CONICAL. A wide-band **antenna** in which the driven element or elements are conical in shape. (See **antenna, biconical**.)

ANTENNA, COSECANT-SQUARED. An **antenna** designed to produce special effects wherein the power density pattern varies as the square of cosecant of an angle defined by a line parallel to the earth's surface and the

slant range line of sight. (Used in airborne antennas to lay down a uniform electric field intensity along a line on the earth's surface.)

ANTENNA CROSS TALK. A measure of undesired power transfer through space from one antenna to another. Numerically, antenna cross talk is the ratio of the power received by one antenna to the power transmitted by the other, usually expressed in decibels.

ANTENNA COUNTERPOISE. One or more wires stretched beneath an antenna, but elevated above, and insulated from, the earth. The antenna circuit is completed through the capacitance of the counterpoise to ground. This system has application where a satisfactory connection to ground is not possible or practical. In high-frequency systems, the antenna plus counterpoise is sometimes called the ground-plane antenna.

ANTENNA (HOLLOW) CYLINDRICAL. An antenna containing hollow cylinders as radiating elements. The dipole antenna frequently contains hollow-cylindrical elements in order that desired impedance-matching and bandwidth characteristics may be obtained. (See antenna, dipole.)

ANTENNA, CUBICAL. An array (see antenna array) of elements arranged in a cubical formation.

ANTENNA, DIAMOND. The name sometimes applied to the rhombic antenna. (See antenna, rhombic.)

ANTENNA, DIELECTRIC. An antenna which employs a dielectric as the major component in producing the required radiation pattern.

ANTENNA, DIPOLE. A center-fed antenna, which is constructed to be approximately one-half as long as the wavelength it is designed to transmit or receive; it is essentially a resonant transmission line system. Also termed "halfwave antenna."

ANTENNA, DIRECTIONAL. An antenna having the property of radiating or receiving radio waves more effectively in some directions than others.

ANTENNA, DIRECTIVE GAIN. Antenna power gain.

ANTENNA, DISCONE. An antenna of a disk and a cone whose apex approaches and becomes common with the outer conductor of the coaxial feed at its extremity. The center conductor terminates at the center of the disk, which is perpendicular to the axis of the cone. Its most important characteristic is its ability to operate over a very wide bandwidth without a substantial change of input impedance or radiation pattern. The radiation pattern is omnidirectional in a plane perpendicular to the axis of the cone.

ANTENNA, DISH. A continuous or perforated concave antenna usually contoured to a parabolic shape, used for transmitting and/or receiving radio frequency waves in relatively narrow beams.

ANTENNA, DOUBLET. Sometimes referred to as a half-wave dipole or Hertz antenna, it is center-fed and has an over-all length of approximately one-half a wavelength. (See antenna, dipole.)

ANTENNA, DUMMY. A test device which has the necessary impedance characteristics of an antenna and the necessary power-handling capabilities, but which does not radiate or receive radio waves. In receiver practice, that portion of the impedance not included in the signal generator is often called "dummy antenna."

ANTENNA DUPLEXER. A circuit configuration which permits two transmitters (the video and aural transmitters of a television station as an example) to transmit simultaneously from the same antenna without interaction.

ANTENNA EFFECTIVE HEIGHT. The effective antenna height h is found from the following relationship

$$h = \frac{ed}{0.2\omega I}$$

where h is the effective height in meters, e is the measured field intensity in microvolts per meter, d is the distance in kilometers from antenna to point of e measurement, ω is the angular frequency in kiloradians per second, I is the antenna current in amperes at point of energization.

ANTENNA ELECTRICAL HEIGHT (LENGTH). The actual length of the antenna in terms of wavelengths or fractions thereof. Applicable only in systems with sinusoidal current distribution.

ANTENNA, END-FED ZEPPELIN. An adaptation of the basic half-wave Hertz antenna. (See **antenna, Hertz**.) It is used when the feeders must be at the end of the antenna because of the location of the equipment.

ANTENNA, FANNED BEAM. A unidirectional antenna so designed that transverse cross sections of the major lobe are approximately elliptical.

ANTENNA FIELD GAIN. The ratio of the effective free space field intensity produced at one mile in the horizontal plane expressed in millivolts per meter for 1 kilowatt antenna input power to 137.6 mv/m.

ANTENNA, FISHBONE. An antenna consisting of a series of coplanar elements arranged in collinear pairs, loosely coupled to a balanced transmission line.

ANTENNA, FLAGPOLE. The name sometimes applied to the coaxial antenna (see **antenna, coaxial**) because of its flagpole-like appearance.

ANTENNA, FOLDED DIPOLE. An antenna composed of two parallel, closely spaced dipole antennas (see **antenna, dipole**) connected together at their ends with one of the dipole antennas fed at its center.

ANTENNA, GAIN. A measure of the directivity of the antenna field pattern as compared to a standard dipole antenna; the ratio of the power that must be supplied to the standard antenna to deliver a certain field strength in the desired direction to the power that must be supplied to the directional antenna to obtain the same strength in the same direction.

ANTENNA, HELICAL. An antenna used where circular polarization is required. The driven element consists of a helix supported above a ground plane. If the circumference of one turn is approximately one wavelength the radiation is said to be in the axial mode and is directed predominately along the axis of the helix. In this mode the antenna has

good efficiency and relatively broad bandwidth.

ANTENNA, HORN. The flared end of a radar wave guide, designed for efficient radiation of energy from within the guide to space over a comparatively wide frequency range. There are the following varieties of horn antennas: biconical, box, compound, pyramidal, and sectoral (an electromagnetic horn, two opposite sides of which are parallel and the two remaining sides of which diverge. The electromagnetic field in such a horn can be expressed by a family of cylindrical coordinates). E-plane and H-plane sectoral horns flare to increase their apertures in a plane perpendicular to the magnetic and electric vectors respectively.

ANTENNA, IMAGE. An antenna located close to the earth's surface (assumed to be a perfectly-conducting plane) transmits a direct ray, and a ray reflected from the earth's surface. It is convenient to represent the reflected ray as originating from an image antenna identical to the original, and located inside the earth by a distance equal to the height of the original above the earth.

ANTENNA INPUT RESISTANCE. Antenna resistance.

ANTENNA, ISOTROPIC (UNIPOLE). A hypothetical antenna radiating or receiving equally in all directions. A pulsating sphere is a unipole for sound waves. In the case of electromagnetic waves, unipoles do not exist physically, but represent convenient reference antennas for expressing directive properties of actual antennas.

ANTENNA, J. A half wave antenna, ended by a parallel wire quarter wave section having the configuration of the letter "J."

ANTENNA, LEAKY-PIPE. An antenna by which external radiation is produced by providing a hole or slot in a waveguide propagating electromagnetic power. Proper choice of the size and location of a series of holes in the waveguide may lead to directional radiation-patterns.

ANTENNA, LENS. To satisfy high directivity requirements, a lens is often placed in front of another radiator such as a dipole or horn. In much the same manner as an optical

lens focuses light waves, these microwave lenses focus the high-frequency energy into a sharp beam.

ANTENNA, LENS (ARTIFICIAL DIELECTRIC OF). The function of the dielectric is to delay the portion of the **wavefront** going through the middle of the lens. These lens are sometimes called "delay lenses" for this reason. Because of their weight, dielectric lenses made from such materials as polystyrene are not usually used in microwave lenses. Instead an artificial dielectric is produced by supporting small metal disks or spheres in a lattice arrangement to simulate the molecules of a true dielectric. This lens is quite broadband.

ANTENNA, LENS (METALLIC). Parallel metal surfaces placed parallel to the **E field** produced by a radiator. Since the **phase velocity** in **waveguide** is larger than the free-space velocity, the net phase change at a given point may be controlled by varying the length of the path the wave travels between the surfaces. Thus a spherical wave may pass through the lens and emerge a plane wave because of the selective phase-shift functions performed. (See **antenna, lens**.)

ANTENNA, LENS (PATH LENGTH). This lens retains the hyperbolic shape of the artificial dielectric lens, but contains parallel conducting sheets which are perpendicular to the **E field**. The sheets may be corrugated or set at an angle to produce a longer path length through the lens than through free space, so that an equivalent **angle of refraction** is produced.

ANTENNA, LINDENBLAD. Four in-phase dipoles (see **antenna, dipole**) arranged uniformly about the circumference of a circle in the horizontal plane, each of the dipoles being rotated in the same direction in a vertical plane about their respective center points. This gives an omnidirectional coverage, with a circular polarization.

ANTENNA, LONG WIRE. A linear antenna that is long in comparison with its operating wavelength, thereby providing a directional radiation pattern.

ANTENNA, LOOP. An antenna having a circular shape or other figure similar to a loop. It consists of one or more complete

turns of wire all lying in the same plane. A rhombic loop antenna is an end-fed type having the appearance of a diamond, and formed of two mirror-reflection halves.

ANTENNA, MARCONI. A quarter-wave antenna one end of which is always grounded, so that the antenna appears effectively as a half-wave type because of the reflection of the radio wave.

ANTENNA, MARKER. The transmitting antenna for a **marker beacon**.

ANTENNA, MULTIPLE-TUNED. A low-frequency antenna having a horizontal section with a multiplicity of tuned vertical sections.

ANTENNA MULTIPLEX COUPLER. A device which combines the FM outputs of the four telemetering packages into one composite FM signal. The signal is applied to the telemetering antennas for transmission to the ground equipment.

ANTENNA, MUSA. A "multiple-unit steerable antenna" consisting of a number of stationary antennas, the composite major lobe of which is steerable.

ANTENNA, NOTCH. Antenna, slot.

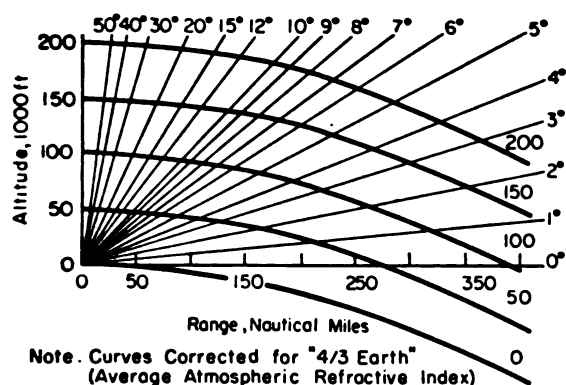
ANTENNA, OMNIDIRECTIONAL. An antenna producing essentially constant **field strength** in azimuth, and a directive **radiation pattern** in elevation.

ANTENNA, PARABOLIC. A directional antenna (see **antenna, directional**) using some form of a paraboloidal mirror either to convert plane waves into spherical waves or to convert spherical waves into plane waves. The **reflector** is fed or "illuminated" by the use of dipoles, waveguide feed systems, or horns. The simple parabolic mirror is truly a broad-band device.

ANTENNA, PARASITIC. An antenna element that operates as a part of an **array** without direct connection to the source of power (or in the case of a receiver, without connection to the receiver terminals).

ANTENNA, PATTERN. A diagrammatic representation of the radiation field from an antenna, usually in terms of loci representing equal power levels. The radiation characteristics vary inversely as the square of the

distance and depend on direction from the source. (See diagram.)



Antenna pattern-temperature-range relationships.

ANTENNA, PENCIL-BEAM. A unidirectional antenna (see **antenna, unidirectional**), so designed that cross sections of the **major lobe** by planes perpendicular to the direction of maximum radiation are approximately circular.

ANTENNA, PILL-BOX. A cylindrical parabolic reflector enclosed by two plates perpendicular to the cylinder, so spaced as to permit the propagation of only one mode in the desired direction of polarization. It is fed on the focal line. The name of the antenna is derived from its shape which is like a very thin circular medicinal pill-box, cut across the diameter so as to have the appearance of half of a circular pie.

ANTENNA, POCKET. A non-protruding slot antenna (see **antenna, slot**) developed for aircraft applications.

ANTENNA POLYROD. A form of dielectric antenna (see **antenna, dielectric**) made of polystyrene rods.

ANTENNA POWER GAIN. In a given direction 4π times the ratio of the **radiation intensity** in that direction to the total power delivered to the antenna.

ANTENNA, QUARTER-WAVE. An antenna which is electrically one-quarter of a wavelength long. It may be physically longer or shorter than one-quarter wavelength in free space. The quarter-wave spike is one such type for short wavelengths, and the Marconi is another name for long wave radio antennas of similar arrangement. In each instance the

supported end is grounded to give one-half wave characteristics by means of surface reflections.

ANTENNA RADIATION RESISTANCE. Radiation resistance.

ANTENNA, RECEIVING. An antenna used for the reception of radiated electromagnetic waves.

ANTENNA RESISTANCE. The quotient of the power supplied to the entire **antenna circuit** by the square of the effective antenna current referred to a specified point. Antenna resistance is made up of such components as **radiation resistance**, ground resistance, radio-frequency resistance of conductors in the antenna circuit, and equivalent resistance due to corona, eddy currents, insulator leakage, and dielectric power loss.

ANTENNA RESONANT FREQUENCY. That frequency or frequencies at which the antenna appears as a pure resistance.

ANTENNA, RHOMBIC. An antenna composed of long-wire radiators comprising the sides of a rhombus. The antenna usually is terminated in an impedance. The sides of the rhombus, the angle between the sides, the elevation, and the termination are proportioned to give the desired **directivity**.

ANTENNA, ROTARY. Any form of antenna which may be rotated around its center in order that its directional characteristics may be used to advantage.

ANTENNA, SCANNING. A directional antenna (see **antenna, directional**) employed in radar which mechanically or electrically causes its radiation pattern to scan periodically a given arc or solid angle.

ANTENNA, SECTIONALIZED VERTICAL. A vertical antenna which is insulated at one or more points along its length. The insertion of suitable reactances or applications of a driving voltage across the insulated points results in a modified current distribution giving a more desired **radiation pattern** in the vertical plane.

ANTENNA, SERIES-FED VERTICAL. A vertical antenna which is insulated from ground and energized at the base.

ANTENNA SERIES LOADING. A method of tuning whereby the effective height of a vertical colinear array may increase with proper nonradiating impedances employed between the elements. (See **antenna, colinear**.)

ANTENNA, SHAPED-BEAM (PHASE-SHAPED). A unidirectional antenna (see **antenna, unidirectional**) whose major lobe differs materially from that obtainable from an aperture of uniform phase. A cosec² θ beam is a shaped beam whose intensity in some plane varies as cosec² θ over a prescribed range, where θ is a polar angle in that plane. The half-power width in planes, perpendicular to this plane, is approximately constant for the prescribed range of θ .

ANTENNA, SHUNT-FED VERTICAL. A vertical antenna (see **antenna, vertical**) connected to ground at the base and energized at a point suitably positioned above the grounding point.

ANTENNA, SIMPLE DOUBLET. Antenna, doublet; antenna, dipole.

ANTENNA, SKIRT DIPOLE. An antenna formed from the coaxial line itself. It is actually a type of coaxial line termination in which the wings of the dipole consist of the unshielded section of the inner conductor, and the folded-back section of the outer conductor. This folded back section is the "skirt."

ANTENNA, SLEEVE-DIPOLE. A dipole antenna (see **antenna, dipole**) surrounded in its central portion by a coaxial sleeve.

ANTENNA, SLOT. An antenna consisting of a resonant cavity, formed by cutting a slot in a metal surface. (The slot may be filled with a dielectric material.) This antenna is used for microwave frequencies. The direction of current flow must be perpendicular (or inclined) to the long dimension of the slot.

ANTENNA, SPACED. An antenna array used for diversity reception, consisting of several antennas spaced several wavelengths apart.

ANTENNA, SPHERICAL. A theoretical radiator, spherical in shape.

ANTENNA, SPIDER-WEB. An antenna array consisting of several, different length

doublets coupled to a common transmission line for wide band (standard broadcast and shortwave) reception. Suitable frequency-sensitive elements are used, so that essentially only one antenna functions at a given frequency. The name is derived from its physical appearance.

ANTENNA, SQUARE LOOP. An array (see **antenna array**) consisting of four dipole radiators arranged in a square. The dipoles may take the form of folded or simple dipoles fed at the center.

ANTENNA, STEERABLE. A directional antenna (see **antenna, directional**) whose major lobe (see **lobe, major**) can be readily shifted in direction.

ANTENNA, TOP-LOADED VERTICAL. A vertical antenna (see **antenna, vertical**) so constructed that, because of its greater size at the top, there results a modified current distribution giving a more desirable radiation pattern in the vertical plane. A series reactor may be connected between the enlarged portion of the antenna and the remaining structure.

ANTENNA, TRIDIPOLE. An omnidirectional, horizontally-polarized antenna consisting of three dipoles displaced from each other by 60° in the horizontal plane. The radiators are curved, causing the array to have a circular appearance.

ANTENNA, TURNSTILE. An antenna composed of two dipole antennas (see **antenna, dipole**), normal to each other, with their axes intersecting at their midpoints. Usually, the currents are equal and in phase quadrature.

ANTENNA, UNIDIRECTIONAL. An antenna which has a single well-defined direction of maximum gain.

ANTENNA, UNIDIRECTIONAL COUPLET. A two-dimensional array made up of pairs of isotropic antennas spaced a quarter wave apart and phased by a quarter period. The directional pattern of each pair is a cardioid. This is thus a type of broadside array. (See **antenna, broadside array**.)

ANTENNA, UNIPOLE. A hypothetical antenna radiating or receiving equally in all directions. A pulsating sphere is a unipole for

sound waves. In the case of electromagnetic waves unipoles do not exist physically but represent convenient reference antennas for expressing directive properties of actual antennas. Also called an "isotropic antenna."

ANTENNA, V. A V-shaped arrangement of conductors, balanced-fed at the apex, and with included angle, length, and elevation proportioned to give the desired **directivity**.

ANTENNA, WAVE (BEVERAGE ANTENNA). A directional antenna (see **antenna, directional**) composed of a system of parallel, horizontal conductors from one-half to several wavelengths long, and terminated to ground at the far end in its characteristic impedance.

ANTENNA, YAGI. An array of center-fed **dipoles** one half wave-length long with any number of auxiliary dipoles in front of it and one behind. The entire array of antennas is fixed in a single plane with the basic dipole antenna next to last in line. The antenna behind is called the "reflector" and all those in front (from 3-10 in number) are called the "directors."

ANTICLASTIC CURVATURE. Curvature of an edge-loaded thin sheet under compression due to the **Poisson effect**.

ANTICOINCIDENCE CIRCUIT. A circuit with two input terminals which delivers an output pulse if one input terminal receives a pulse, but delivers no output pulse if pulses are received by both input terminals simultaneously or within an assignable time interval. (See **resolving time; coincidence**.)

ANTICOINCIDENCE COUNTER. An arrangement of **counters** and associated circuits which will record a count if and only if an ionizing particle passes through certain of the counters but not through the others.

ANTICYCLONE. A large atmospheric eddy, whose horizontal dimensions vary from a few hundred miles to several thousand miles. It rotates in a clockwise manner in the northern hemisphere and a counterclockwise manner in the southern hemisphere when viewed from above. The barometric pressure within an anticyclone is high relative to its surroundings, and a pressure gradient exists from its center toward its periphery. A well-developed anticyclone is essentially an **air mass**.

ANTICYCLOTRON. A form of **traveling-wave tube**.

ANTI HUNT TRANSFORMER. A transformer used in d-c **feedback systems** as a stabilizing network. In general practice the primary of this transformer is in series with the load connected to the system. The secondary of the transformer has a voltage which is proportional to the derivative of the primary current, and is thus an appropriate signal to be fed back into some other part of the **loop** to prevent self-oscillations.

ANTI HUNTING CIRCUIT. A stabilizing or equalizing circuit used in a closed-loop **feedback system** to modify the response of the system in order that self-oscillations may be prevented.

ANTIMISSILE MISSILE. A **missile** launched to intercept another missile in flight.

ANTIMISSILE PROBLEM. Specifically, the antiballistic missile problem in the time domain. The title refers to the whole area of problems involved in the early detection and destruction of such missiles. Since the minimum duration of an object in a Keplerian ellipse oriented about the earth would be 84 minutes, and it is commonly accepted that ballistic missiles would be used no more than half-way around the earth, the theoretical flight time for this trajectory would be 42 minutes. If any portion of the missile's trajectory is by means of aerodynamic support this time will be increased considerably but would still be only a matter of perhaps one hour or less. This very short period means that any counter missiles prepared to intercept enemy ballistic missiles must be within a few minutes of "ready to fire" at all times. Crews must be standing by within minutes of their equipment. Radars or other detecting equipment must be searching the space toward the enemy at all times. Extreme precision in guidance and warhead detonation must be attained to obtain an effective interception. Two missiles approaching head-on at a combined countervelocity of Mach 20 to 40 means that microsecond reactions must be possible. The problem is so demanding in techniques that it appears the probable antimissile solution will be to have some satellite reconnaissance system able to detect the enemy missile during its early preparation phase.

ANTIMONY. Metallic element. Symbol Sb. Atomic number 51.

ANTINEUTRON. The **antiparticle** of the **neutron**. A research team at the University of California's Bevatron laboratory discovered the antineutron in the course of determining the collision **cross section** of **antiprotons** in liquid hydrogen. The antiproton gives a negative charge to the proton during a "near miss," thus making both particles neutral—the proton is transformed into a neutron, and the antiproton becomes an antineutron. This is a charge exchange process.

ANTINODES (LOOPS). The points, lines, or surfaces in a standing wave (see **wave, standing**) system where some characteristic of the wave field has maximum amplitude. The appropriate modifier should be used with the word "antinode" to signify the type that is intended (pressure antinode, velocity antinode, etc.) (See also **loop**.)

ANTIPARALLEL. Having opposite senses, as two vectors which are parallel, but which are placed head to tail.

ANTIPARTICLE. The prefix **anti-** added before the name of an elementary particle denotes another particle with certain symmetry characteristics. In the case of a charged particle, such as a **proton**, the antiparticle is the **antiproton**, which has a charge equal and opposite to that of the proton, and which has a magnetic moment that is oppositely directed with respect to its spin, compared to their mutual orientation in the particle. The relation between **positron** and **electron** is the same as that between proton and antiproton. In the case of a neutral particle, such as a **neutrino**, there is no charge, and differentiation is made on the second basis; that is, the distinguishing difference between the neutrino and the antineutrino is that the magnetic moment is oppositely directed with respect to the spin, compared to their mutual orientation in the particle. The relation between **neutron** and **antineutron** is the same as that between neutrino and antineutrino.

It is of course to be noted that there are other differences between these various particles, such as in their **lifetimes** or **half-lives**.

ANTIPLUGGING RELAY. A **relay** used in some control systems to prevent **plugging**.

ANTIPODAL BOMBER. During World War II, Dr. Eugen Saenger proposed a supersonic bomber project which involved a rocket-powered manned missile fired first above the sensible atmosphere to a high velocity. As the missile fell back toward the atmosphere it would be programmed to approach in a relatively flat dive. The manned portion of the system was then supposed to skip along the upper layers of the earth's air as a supersonic glider on small airfoils. The propulsion unit was a LOX-oil rocket with a quarter million pound thrust. Take-off weight was to be 100 tons with an empty weight of 10 tons and a 0.3 ton payload.

The missile was to be launched on a horizontal track 1.8 miles long with the assistance of boosters giving 1,650 feet per second velocity at the end of the track. The vehicle would then enter a 30 degree climb which it would maintain until it reached a velocity of 19,680 feet per second. Maximum altitude was to be 155 miles. Maximum range 14,600 miles.

The history of the antipodal bomber project dated back to 1933 when Dr. Saenger published his book *The Technique of Rocket Flight*. Work on the concept was done by the Germans during World War II but was stopped in 1942 when it appeared that the program could not be finished in time to affect the outcome of the war. The military project envisioned a missile of take-off weight of 220,500 pounds, 92 feet in length with a span of 49 feet. Maximum velocity was to be 13,660 mph at an altitude of 93 miles. Thrust was to be 100 tons for 8 minutes. Catapult launching was to boost the velocity to 1.5 Mach when the rocket motors would cut in. This was similar in theory (supersonic glider idea) to the A-9/A-10 system but was not the same project.

ANTIPROTON. An elementary particle having a mass essentially equal to that of the proton, differing from the proton in the sign of its charge, which is negative. Its detection was announced by the University of California and the U.S. Atomic Energy Commission. Protons which had been accelerated to an energy of 6,200 mev in the **bevatron**, the proton synchrotron of the University of California Radiation Laboratory at Berkeley, were allowed to collide with a copper target. Negatively-charged particles coming out in a for-

ward direction from this collision were selected and separated in momentum by a focusing and analyzing magnet system to provide a beam of negative particles of known momentum. After a time of flight of about one-tenth of a microsecond, this beam may be expected to consist mainly of negative pi- and mu-mesons, with some negative K-mesons (mass about 965 electron masses) and possibly negative protons. These particles were then distinguished both by measurement of their time of flight from the target (since particles of different mass have different velocities for given momentum) and by means of a device measuring the velocity of each particle passing through by the angle of its Cerenkov radiation. In this way the presence of negative particles with protonic mass (within about ten per cent) and distinct from the known K-particles and hyperons was established. Their rate of production for the momentum and direction of this experiment was about one negative proton for every 50,000 negative pi-mesons with the same momentum and direction. (See **antiparticle**.)

ANTIS. Antimissile weapons systems.

ANTITRADE WINDS. Above the northeast and southeast trade winds there frequently is present westerly winds known as the antitrades. Reversal of direction occurs as low as a few thousand feet or as high as 3-4 miles.

ANTITRANSMITTER-RECEIVER. A device used in microwave radar so as to utilize the same antenna in transmitting and receiving.

ANTI-TRANSMIT-RECEIVE SWITCH. Transmit-receive switch, duplexer.

ANVIL. The characteristic fibrous, spreading top of a cumulonimbus cloud in full development.

APERIODIC CIRCUIT. A circuit which is not resonant to a definite frequency. The antenna circuit of most broadcast receivers is an aperiodic circuit inasmuch as it is not tunable to various frequencies.

APERIODIC COMPASS. A magnetic compass having a highly damped indicator to prevent overswing or oscillation.

APERTURE. Qualitatively, any opening through which radiation or particle fluxes may

pass. In optical and electron-optical instruments, the term aperture has acquired specific or quantitative meanings given below.

APERTURE OF A LENS. The diameter of the lens.

APERTURE OF A UNIDIRECTIONAL ANTENNA. That portion of a plane surface near the antenna, perpendicular to the direction of maximum radiation, through which the major part of the radiation passes.

APERTURE, RELATIVE (OR F-NUMBER). The ratio of the focal length of an optical system to the diameter of the entrance pupil.

APERTURE STOP. That opening in an optical system, frequently one of the lenses itself, which limits the size of the bundle of rays which can pass from a point on the object to the corresponding point of the image. The aperture stop of a system may be a different opening for objects at different distances from the system.

APGC. Air Proving Ground; Eglin Air Force Base; Valparaiso, Florida.

APHELION. (1) The position of a planet, comet, or other body (especially the earth) in its orbit where it is most distant from the sun. (2) The position of a satellite in its orbit where it is most distant from the earth.

APL/JHU. Applied Physics Laboratory/The Johns Hopkins University; Silver Spring, Maryland.

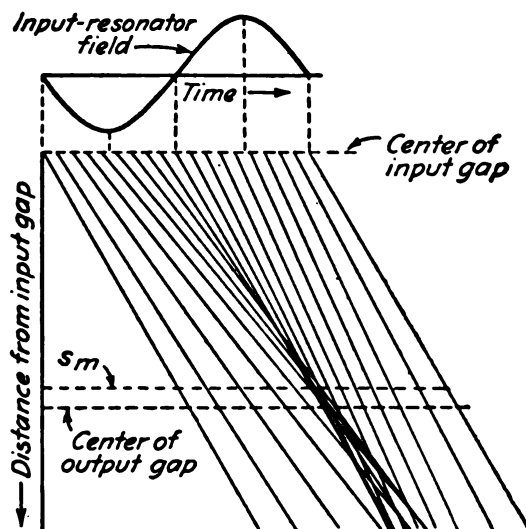
APOGEE. (1) The point on the orbit of a satellite which is at the greatest distance from the center of the earth; apogee is the opposite of perigee. Note that the apogee is a point, not a distance. (2) The highest point of a trajectory of a missile. (3) More precisely for any elliptical orbit, the point of intersection of the ellipse and its semi-major axis.

APPARENT PRECESSION. The relative angular movement of the spinning axis of a gyroscope in relation to a line on the earth, resulting from the rotation of the earth and the property of the gyroscope to maintain its spinning axis in the same direction in space.

APPARENT SOLAR TIME. The time indicated by the position of the sun. The time is

"apparent" since the orbit of the earth about the sun is elliptical; therefore the movement of the sun in the celestial sphere is not uniform.

APPLEGATE DIAGRAM. A graphical explanation of the process of bunching in **velocity-modulation** tubes. The example below is for the two-cavity **klystron**. In this diagram the positions of electrons that pass through the output gap at various instants in the cycle of buncher voltage is shown as a function of time. The slope of any curve is equal to the velocity with which the corresponding electron leaves the input gap.



Applegate diagram (By permission from "Micro-wave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc.)

Close spacing of the velocity lines indicates that many electrons pass a given point in a short time interval, that is, that the electrons pass in bunches.

APPLETON LAYER. The F layer of the ionosphere.

APPLICATOR (APPLICATOR ELECTRODES). In dielectric heating usage, appropriately-shaped conducting surfaces between which is established an alternating electric field for the purpose of producing **dielectric heating**.

APPLIED SHOCK. Any excitation which, if applied to a system, would produce **shock motion** within the system.

APPLIED VOLTAGE. Voltage, applied.

APPRESSION. The sensation of weight. Lack of appression is **weightlessness**.

APPROACH APRON. A concrete apron adjoining the erection area that provides a solid support surface for ground handling equipment for **missiles**.

APS. Accessory Power Supply.

APSE. Apsis.

APSIDAL. An adjective referring to an **apsis**.

APSIS. The point on an orbit at which the distance of the body from the center of attraction is either a maximum or a minimum. In an elliptic orbit, the apsis of maximum distance from the center of attraction is called the apo-apsis; and the apsis of minimum distance from the center of attraction is the peri-apsis. For the earth's orbit, the corresponding terms are apogee and perigee. Sometimes the apo-apsis is called the higher apsis, and the peri-apsis, the lower apsis.

APU. Auxiliary Power Unit.

AQ. Aircraft Quality.

AQL. Acceptable Quality Level.

AQUARIUS. (The water bearer.) This constellation is the eleventh sign of the zodiac and is of importance solely because of that fact. There is a theory that the constellation received its name because the sun is in this part of the sky during the rainy season in the Euphrates valley.

Though the constellation is relatively large it contains no bright or particularly striking features.

AQUILA. (The eagle.) A constellation lying in the **milky way** and hence containing rich star fields when viewed with a low-powered telescope. The distinguishing feature of this constellation is the group of three stars almost in a straight line, with the bright

star Altair between two fainter ones. Several Novae have appeared in this constellation, the most famous one being Nova Aquilae III of 1918.

AR-1. An aircraft rocket motor developed by Rocketdyne.

ARC. A low-voltage, high-current electrical discharge, as contrasted with a spark.

ARC BACK (BACKFIRE). This is the occurrence of an arc from **anode** to **cathode** in a **gaseous rectifier tube**. Normally such a tube has **electrons** flowing from the cathode to the anode but under certain conditions excessive heating of the anode, excessive voltage across the tube, or other effects may cause the anode to emit electrons and allow an arc discharge to take place in a direction opposite to the normal direction. Under many circuit conditions this may destroy the tube or it may merely open the protective devices.

ARC CONVERTER. A form of **oscillator** utilizing an electric arc as the generator of alternating or pulsating current.

ARC DISCHARGE. The electric arc, so called because of the shape of the "flame," was discovered by Davy about 1808. It is a



type of discharge between electrodes in a gas or vapor which is characterized by a relatively low voltage drop and a high current density. The two types which are of considerable practical importance are the arc in open air and the arc in gases at low pressure. The familiar carbon-arc (see **arc lamp**) and the electric-arc furnace are examples of the former. The **mercury-arc tube** is the most important example of an arc in a gas at low pressure.

ARC LAMP. The electric-arc lamp has, as its source of illumination, an electric arc struck between two electrodes. In contrast to the incandescent lamp, in which the illumination results from a heated filament, and vapor lamps, in which the illumination is derived from a vapor made luminous by electric current, the light from an arc lamp comes from the highly incandescent crater of the positive electrode, and from the heated, luminous, ionized gases surrounding the arc.

ARCHIMEDES PRINCIPLE. A body immersed in a fluid is acted upon by a buoyancy

force, made evident by a loss of weight, equal to the weight of the fluid displaced.

ARCTIC SMOKE. A form of fog caused by rapid evaporation from the surface of warmer water when very cold, dry air streams across it.

ARCTURUS (α BOOTES). Arcturus was probably one of the first stars to be named. It probably received its name because of its proximity to the constellation of **Ursa Major**, the name indicating that it is the "watcher of the bear."

Arcturus is one of the few stars whose diameter has actually been measured with the stellar **interferometer**. The angular diameter is found to be $0''.020$ which, when combined with its **stellar parallax** of $0''.080$, indicates a linear diameter of about 27 times that of our sun.

ARDC. Air Research and Development Command; Baltimore, Maryland.

AREA. (1) If a parallelogram has sides denoted by the vectors **A** and **B**, its area is given by the vector product, $\mathbf{C} = \mathbf{A} \times \mathbf{B}$, which is perpendicular to the plane determined by **A** and **B**. The scalar magnitude of **C** equals that of the area and the direction of **C** is arbitrarily taken as the direction of the outward normal to the surface. (2) In **calculus**, the area of a surface may be found by integration. If $y = f(x)$ describes a curve, the area bounded by the curve, the **X-axis**, and the ordinates (a, b) is

$$\int_a^b f(x)dx.$$

A double integral may also be used, for an infinitesimal **surface element** in the **XOY-plane** is $dx dy$ and the area over a region **S** is

$$\iint_S dx dy.$$

For a curved surface described by $z = f(x, y)$ the area is

$$\iint_S f(x, y) dx dy.$$

Areas of some common geometrical figures are given in the following table:

AREAS OF SOME COMMON GEOMETRICAL FIGURES

Prism or cylinder	$L = ep$	where e is the edge and p is the perimeter
Circular cylinder	$L = 2\pi rh$	where h is the altitude
Prism or cylinder	$T = L + 2B$	where B is the area of base, T is the total area and where L is the area of faces
Regular pyramid	$L = \frac{1}{2}sp$	where s is the sectional height and p is the perimeter of base
Circular cone	$L = \pi rs$	where s is the slant height
Frustrum of a regular pyramid	$L = \frac{1}{2}s(p_1 + p_2)$	where p_1 is the perimeter of lower base and p_2 is the perimeter of upper base
Frustrum of a right circular cone	$L = \pi s(r_1 + r_2)$	where r_1 is the radius of lower base and r_2 is the radius of upper base.
Frustrum of a cone or pyramid	$T = L + B_1 + B_2$	where T is the total area
Sphere	$S = 4\pi r^2$	
Spherical triangle	$S = \left(\frac{\alpha}{720}\right) 4\pi r^2$ $= \frac{\alpha}{180} \pi r^2$	
Lune	$S = \frac{2\alpha}{720} 4\pi r^2$ $= \frac{\alpha}{90} \pi r^2$	α = angle of the lune in degrees.
Zone	$S = 2\pi rh$	where h is the distance from the pole to the plane of a great circle.

AREA, EFFECTIVE. The flared end of radar **waveguide**, which has been matched to the surrounding space for efficient radiation of energy from within the guide to space.

AREA, EQUIVALENT FLAT-PLATE. In aerodynamics the area of a square flat plate, normal to the direction of motion, which offers the same amount of resistance to motion as the body or combination of bodies under consideration.

AREA, EXPOSED. The area of the wing (or tail) outside the fuselage.

AREA RULE. A technique of supersonic design consisting of narrowing the aircraft fuselage to "wasp waist" at the wing root in order to reduce interference drag. This eliminates shock waves at the junction of the wing and airframe. If indenting is impractical, the same effect can be achieved by bulging the fuselage fore and aft of the wing junction. This narrowing provides in effect an expanding

volume for shocked air to fill rather than to pile up against the wing and fuselage. This greatly reduces the wing drag and consequently the force required to propel the vehicle under supersonic conditions.

AREA-RULE CONCEPT. A concept of design based on the notion that interference drag at transonic speed depends almost entirely on the distribution of the aircraft's total cross-sectional area along the direction of flight.

ARGAND DIAGRAM. A graphical method of representing a function of a complex variable, $z = x + iy$. There are two perpendicular axes, the real part of the function being plotted on the real axis, usually the horizontal one, and the imaginary part on the imaginary or vertical axis. Points plotted on the diagram for various values of the number pair (x, y) can then be joined to give a curve for the function in the complex plane.

ARGON. Gaseous element, present in the atmosphere. Symbol A. Atomic number 18.

ARIES. (The ram.) This constellation is far more famous from its classical significance than because of its appearance in the sky. It contains no bright stars and has no conspicuous features. Two thousand years ago the **vernal equinox** was located in the constellation of Aries and the symbol for the vernal equinox is the symbol for the constellation (i.e., the ram's head). Precession has caused the position of the vernal equinox to move backwards into the constellation of **Pisces** so that now the "sign of the first of Aries" is to be found in that constellation.

ARINC. Aeronautical Radio, Incorporated.

ARITHMETIC UNIT. That part of a computer which performs arithmetic operations.

ARL. Acceptable Reliability Level.

ARM. (1) To change a weapon from a safe condition to one of readiness for initiation. Fuzes for ordnance are armed by acceleration, rotation, air travel, ground command; by clock mechanisms or altitude sensing devices; or by combinations of these methods and devices. (2) To remove all safety devices so that a dangerous device is ready to operate. The term may refer to the fuze, the warhead device as a whole or some part of it. Arming may refer to the actual commencement of the firing cycle or it may merely refer to a preparatory "cocking" of the mechanism. Arming of artillery projectiles is usually accomplished by an acceleration set-back device, sensitive in either a linear or rotational direction. Arming of aerial bombs is usually managed by a break-away wire connected to the aircraft and the bomb fuze. Arming may also be accomplished by the turning of a small "air log" mounted in the nose of the bomb as it falls through the air. Arming can also be by electronic timing, chemical action (as in mines), and a variety of other ways.

ARMAMENT. Guns, ammunition and explosive materials including bombs, propellants, rockets, pyrotechnics and incendiary compounds, protective armor, equipment for dispensing toxic and biological warfare materials, sights, computers, launchers, control systems, together with the necessary components, accessories, supplies, fixtures and test equipment.

ARMAMENT SYSTEM. A triad of missile components; fuze; safety and arming mechanism and warhead—which are used to produce and control the damage effects of a missile.

ARMATURE. (1) The rotating part of a direct current motor or generator. It is the part of the generator that delivers electrical energy and the part of the motor that receives energy. (2) The moving element of a loudspeaker. (3) The reed of a relay.

ARMED. That condition of the safety and arming mechanism which permits warhead detonation by fuze action.

ARMING. (1) The act of completing the firing signal transfer path through the S and A (Safety and Arming System). (2) The process of changing a fuze or a warhead from a safe condition to a state of readiness for initiation.

ARMING ALTITUDE. The altitude dictated by the combined effects of several extreme conditions, including the maximum desired burst height, the highest target elevation expected.

ARMING SYSTEM. Safety and Arming Mechanism.

ARMY-NAVY NUMBERING SYSTEM. A-N System of Nomenclature for Electronic Equipment.

ARO. Army Research Office.

ARPA. Advanced Research Projects Agency.

ARRAY. (1) A collection of numbers or functions ordered into tabular form, such as a determinant or matrix. (2) See **antenna, array.**

ARRHENIUS EQUATION. A relationship for the effect of temperature on the rate of a chemical reaction. A convenient form of it is:

$$\frac{d \ln k}{dT} = \frac{E}{RT^2}$$

where k is the rate of reaction, E is the activation energy, R is the gas constant and T is the absolute temperature. In its integrated form, this equation becomes

$$\ln k = -\frac{E}{RT} + C$$

ARROW STABILITY. The arrangement of the center of pressure and center of gravity in a missile configuration so that there is a natural aerodynamic stability of flight through the sensible atmosphere based upon the same principles as apply to an arrow (i.e., a heavy head and tail fins). A missile which is arrow-stable would have a center of gravity well forward toward the nose, and a center of pressure well to the rear toward the tail. Arrow stability is effective only under conditions where air drag has influence upon the body surfaces. It has a disadvantage in aircraft rockets, when such rockets are desired to be fired in a direction other than directly forward from the aircraft. Thus finned projectiles fired broadside from a high speed aircraft tend to "weathercock" into the relative wind. This has caused consideration to be given to spin-stabilized rockets which are spun by offsetting the exhaust jets, and which include folding fins that open only after the missile has attained an appreciable velocity on the desired heading.

ARROW WINGS. A name sometimes given to backward swept wings, which are used to reduce drag at high speeds.

ARS. Advanced Reconnaissance System.

ARSENIC. Non-metallic element. Symbol As. Atomic number 33.

ARTICULATION (PERCENT ARTICULATION) AND INTELLIGIBILITY (PERCENT INTELLIGIBILITY). Of a communication system, the percentage of the speech units spoken by a talker or talkers that is understood correctly by a listener or listeners.

ARTIFICIAL HORIZON. (1) A device that indicates the attitude of an air-vehicle with respect to the true horizon. (2) A substitute for a natural horizon, such as a liquid level, pendulum or gyroscope, incorporated in a navigating instrument.

ARTIFICIAL LINE. A network which simulates the electrical characteristic of a **transmission line**.

ARTIFICIAL LOAD. A dissipative but essentially nonradiating device having the impedance characteristics of an **antenna**, **transmission line**, or other practical utilization circuit.

ARTIFICIAL METEORS. Meteors, artificial.

ARTIFICIAL SATELLITE. Satellite, artificial.

As. Arsenic.

ASA. American Standards Association.

ASCENT PATH. Flight path leading from the surface of a celestial body into an orbit in space.

ASCENDING NODE. Satellite elements.

ASCOP. (1) A system of automatic telemetry decommutation used at the U.S. Naval Air Missile Test Center, Pt. Mugu, California. It provides a continuous readout by channel. (2) Applied Science Corporation, Princeton, N.J.

A-SCOPE. A type of **radarscope** that presents the echo in range only; usually on a vertical scale, but in some modified versions on a horizontal scale. (See also **radar oscilloscope presentation**.)

ASDIC. An abbreviation for Anti-submarine Detection Investigation Committee (British). The term is also applied to a system of submarine detection based upon the utilization of inaudible high frequency pulses generated by a **transducer** and reflected to a detecting instrument by a submarine in the path of the projected energy. (See also **sonar**.)

ASESA. Armed Services Electro Standards Committee.

ASETC. Armed Services Electron Tube Committee.

ASG. Aeronautical Standards Group.

ASI. Ammended Shipping Instructions.

ASKANIA CINETHEODOLITE (or **PHOTOTHEODOLITE**). A standard missile proving ground phototheodolite existing in several models. It was originally developed by the Germans for use at their rocket proving grounds at Peenemuende during World War II. Essentially the instrument is a manually operated tracking motion picture camera of long focal length pointed by two operators tracking the missile through separate azimuth and elevation telescopes. The camera is

mounted on a platform capable of highly accurate orientation in attitude and direction. While tracking the missile the camera records the azimuth and elevation angles of the optical axis and simultaneously takes a picture of the missile and its vicinity. Both the missile and the direction readings appear simultaneously on each frame of the developed motion picture film. When used in groups of two or more, the azimuth and elevation angles obtained from each can be correlated in time to yield direction angles to the missile at particular times. These yield the space position of the missile by photogrammetric methods. Since the time of each position is known, differentiation yields the velocity and acceleration of the missile also. The instrument is usually mounted on a rigid cement foundation for orientation stability and because of its weight (approximately 160 pounds).

ASM. Air-to-surface missile. (See **missile, air-to-ground; missile, guided; model designation.**)

ASM-N-4. Air-to-surface Missile, U.S. Navy, (BuOrd) #4. It is the official designation for Eastman Kodak's **Dove**.

ASM-N-7. The Martin Company (U.S. Navy, Bureau of Aeronautics) **Bullpup** missile.

ASP. Atmospheric Sounding Projectile. A U.S. Navy (ONR) sponsored aerographic rocket project. It was a 3500 miles per hour single stage rocket used to gather and telemeter weather data. It was made by Horning Cooper Development Corporation. Its solid propellant motor was developed by Grand Central Rocket Company. It could attain 150,000 feet in 60 seconds. It was 12 feet long and $6\frac{1}{4}$ inches in diameter. (See **missile, guided.**) (See also illustration facing Page 27.)

ASPECT RATIO. (1) The ratio of the square of the span to the total area of an airfoil. $AR = b^2/S$, where b is the tip-to-tip distance across the airfoil, and S is the total area of the airfoil. The term is sometimes written: \mathcal{R} . (2) The ratio of the span to the mean chord of an airfoil. (3) In wingless airframes such as rockets, the ratio of body diameter to mean length. This is also called the Slenderness Ratio. (4) In rocket motor design, the ratio of the length of the combus-

tion chamber to the diameter. Symbolically: $AR_c = l_c/d_c$. (5) The ratio of the width of a cathode ray tube screen to its height. From esthetic reasons the aspect ratio of rectangular tubes is conventionally four units wide to three units high. This makes the most pleasing frame dimensions.

ASPHERIC, ASPHERICAL. Not spherical.

ASPHYXIA. A cessation of breathing due to lack of oxygen, with or without an excess of carbon dioxide; especially as it occurs at very high altitudes.

ASROC. Anti-submarine rocket under development for the Navy (BuOrd) by Minneapolis-Honeywell.

ASSAULT DRONE. Pilotless aircraft developed by the U.S. Navy and used in 1944 against Japanese and German targets. They employed television and radio control in a mother airplane to effect guidance.

ASSEMBLY. (1) A group of component parts, usually mounted, which may be subject to disassembly and which is not capable of performing a complete operation by itself. (2) A combination of parts and/or subassemblies which may be taken apart without destruction and which does not have any application or use of its own, but is essential for the completeness of a more complex item with which it is combined. Assemblies may be referred to as "subassemblies" and "sub-subassemblies," to indicate their relationship to a major assembly. (3) A collection of systems, each consisting of the same number of particles or containers of the same shape, each system having the same total energy, but without any other restriction on the coordinates and momenta.

ASSUMED POSITION. A position, other than the actual position, at which a navigator assumes himself to be for purposes of determining the computed altitude of a given celestial body.

ASTABLE (OR FREE-RUNNING). Referring to a circuit which has two quasi-stable states. No trigger is required; a continuous waveform is generated.

ASTATIC. (1) Without orientation or directional characteristics. (2) A trade name.

ASTATINE. Artificial radioactive element. Symbol At. Atomic number 85.

ASTER. (1) Submarine Torpedo Ordnance Rocket. A supersubmarine killer now in development for the U.S. Navy by Westinghouse Ordnance, Baltimore, Md. (2) Any small piece of detached matter in space. It may fall into an orbit within the gravitational pull of other celestial bodies. A spaceship might be referred to as an aster.

ASTEROID (ASTRON). A starlike body, especially one of the numerous small planets, *nearly* all of whose orbits lie between Mars and Jupiter. Also termed Planetoid and Minor Planet.

ASTIA. Armed Services Technical Information Agency; Dayton, Ohio.

ASTIGMATISM. (1) A defect in a lens, including the lens of the eye, in which there is a difference in the **radius of curvature** of the lens as observed in one plane from that observed in another plane. (2) An **aberration** of a lens with spherical surfaces such that the image of a point not lying on the optical axis is a pair of short lines normal to each other and at slightly different distances from the lens. (3) In an **electron-beam tube**, a focus defect in which the electrons in different axial planes come to focus at different points.

ASTRIONICS. The science of electronics as employed in **astronautics**.

ASTRO. A proposal for the use of an artificial satellite for a reference in a navigational system. The name is derived from Artificial Satellite, Time and Radio Orbit. In essence the plan called for the establishment of one or more artificial bodies in 24 hour orbits so that they would appear motionless in the sky over selected points on the earth's surface.

ASTRO COMPASS. An instrument used to determine direction by sighting heavenly bodies of known position. (See **sun compass**.)

ASTROBIOLOGY. The study of conditions for life on other planets or satellites.

ASTRODOME. A transparent hemisphere used to protect an optical instrument, yet permit observation with it. The navigating bub-

ble on top of aircraft fuselages is an example. An astrodome for very precise instruments such as telescopes or ballistic cameras has a viewing port which may be opened, because even the best designed glass or plastic housing may cause distortions. An astrodome may also include air conditioning equipment. If so, this equipment is used to keep the instrument at a constant temperature selected to be near the outside temperature at the time of use of the instrument. For example, a ballistic camera may be designed to be used at night. All during the day the instrument would be maintained in an air conditioned atmosphere of a temperature equal to that expected at the time of use. Thus, when the viewing port would be opened at night, there would be no danger of fogging of lenses or distortions due to the camera being at a different temperature from the environment.

ASTROLITE. A heat resistant plastic material made by the H. I. Thompson Fiber Glass Company. It is able to withstand temperatures of 4000-5000°F with structural integrity and high impact resistance.

ASTRONAUT. One who travels between planets or other heavenly bodies.

ASTRONAUTICS. The art and science of traveling through space, or of sending guided vehicles or missiles through space. (See also **cosmonautics**.)

ASTRONAVIGATION. The practical science of making use of the stars for finding position and for obtaining directional information for the purpose of steering a course of travel to some destination. On earth, astronavigation is a standard and relatively simple technique. In space, where zero gravity exists in an orbiting vehicle, the "horizon" will not be available since observing instruments using bubbles or plumb lines will be useless. Also, for travel within the solar system, stars cannot be used for determining position since their relative positions are practically the same throughout the solar system. Interplanetary navigation would probably use the sun and planets of the solar system since these move noticeably with respect to one another. If the speed of the vehicle begins to approach the velocity of light, **relativistic time contraction** effects become appreciable or even very great. It is certain that astronavigation for space travel

will be difficult. It may be so difficult that other means based upon the Doppler effect in displacing spectral lines of stars, or in displacing radio waves may be used. It is also possible that inertial reference systems may be the most practical.

ASTRONOMICAL REFRACTION. In any type of astronomical observation the light from the distant object must pass through the atmosphere of the earth and suffer a change of direction known as **refraction**. The amount of change of direction depends upon two fundamental factors: the relative **refractive index** of the atmosphere and the angle which the ray from the distant object makes with the normal to the surface of the atmosphere. Since the normal to the atmosphere is the direction of the astronomical **zenith** the amount of refraction will depend upon the **altitude** of the object, being greatest when the altitude is least, or when the object is on the **horizon**. The effect of refraction is to make the altitude of an object appear greater than it would be if no atmosphere were present.

To calculate the amount of astronomical refraction the index of refraction of the atmosphere is needed and, unfortunately, this quantity varies with meteorological conditions. Various theoretical methods for computing the amount of astronomical refraction have been proposed but none of them are very satisfactory for altitudes less than 20° . A fair approximation to the true value may be obtained from the expression

$$R = \frac{983B}{460 + T} \cotan h$$

in which B is the reading of the **barometer** in inches, T is the **temperature** of the air in degrees **Fahrenheit**, h is the apparent altitude of the object, and R is the amount of refraction in seconds of arc. More accurate values may be obtained by using refraction tables such as those published in Bowditch American Practical Navigator.

ASTRONOMICAL SYSTEM OF MEASUREMENT. A system of measurement of physical quantities and events based upon the assignment of unity to the **gravitational constant**. In this system the astronomical unit of mass (1 *asm*), is 6.223×10^{22} g, or 4.264×10^{18} slugs, and the astronomical unit of force (1 *asf*), is 1.003×10^{28} dynes or 2.25×10^{22}

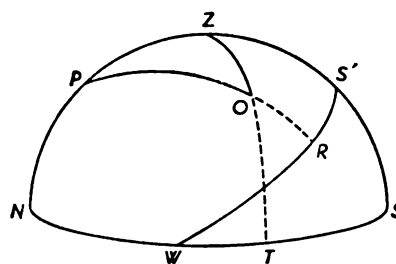
pounds. These units are valid if the units of length are the mile and of time the second. If kilometers and seconds are used,

$$1 \text{ asm} = 1 \text{ km}^3/\text{sec}^2 = \frac{4.264}{4.17} \times 10^{18} =$$

$$1.022 \times 10^{18} \text{ slugs, and } 1 \text{ asf} = \frac{2.25}{6.71} \times 10^{22} \text{ lb}$$

$$= 3.36 \times 10^{21} \text{ lb.}$$

ASTRONOMICAL TRIANGLE. (1) Either a celestial triangle or a terrestrial triangle. Also called a "navigational triangle." (2) The spherical triangle formed on the **celestial sphere** between the observer's **meridian**, the



Astronomical triangle.

hour circle, and the **vertical circle** through an object, is known as the **astronomical triangle**. Since practically every problem of **nautical astronomy** deals with the solution of this triangle it will be well to have the definitions of the various parts well in mind. In the figure (drawn for an observer in the northern hemisphere) we have:

N, *W*, and *S*, the north, west, and south points of the observer's **horizon**.

S', R, W is the celestial equator.

Z is the observer's astronomical zenith.

P is the north pole of rotation.

O is the object under consideration.

PZO is the astronomical triangle, the various parts of which are defined as follows:

The vertex angles are:

ZPO = the hour angle of the object.

$PZO = 180^\circ$ —the astronomical azimuth of the object.

ZOP = the parallactic angle.

The sides (measured in angular units) are:

$PZ = 90^\circ$ —observer's astronomic latitude.

$ZO = 90^\circ$ —**altitude** of the object = zenith distance of the object.

$PO = 90^\circ$ —declination of the object.

ASTRONOMICAL TWILIGHT. The arbitrary period when the center of the sun is between the horizon and a point 18° below the horizon.

ASTRONOMICAL UNIT. A unit of distance principally employed in expressing distances within the **solar system**, but also used to some extent for measuring interstellar distances. Technically defined, one astronomical unit is the mean distance of the **earth** from the **sun**. To express this in miles it becomes necessary to determine the distance of the earth from the sun in miles or, in other words, to determine the **solar parallax**. The value accepted at present for the length of the astronomical unit is 92,897,000 miles (149,504,000 kilometers).

ASTRONOMY. The science concerned with celestial bodies, their magnitudes, motions, constitution, and interrelations.

ASTROPHYSICS. The physics of astronomical bodies, including the study of stellar light, energy sources, constitution of celestial bodies, etc.

ASW. Anti-Submarine Warfare.

ASYMMETRIC. Not symmetric. The term is generally applied only to functions or systems which are neither **symmetric** nor **anti-symmetric**.

ASYNCHRONOUS. Not synchronous or out of step or phase. It also means not having the same frequency.

At. Astatine.

ATC. Air Training Command.

ATEP-14. Monica.

ATHODYD. (Aero *ThermODY*namie Duct). A ramjet.

ATI. Air Technical Intelligence.

ATIC. Air Technical Intelligence Center.

ATLANTIC MISSILE RANGE. The name assigned by the Department of Defense to what was formerly called the Air Force Missile Test Center, Patrick Air Force Base, Florida. The Atlantic Missile Range was established in 1958 as a facility of the Department of Defense including the Cape Canaveral

launching area and all the downrange stations of the Florida Missile Range. It is assigned to the Air Research and Development Command of the U.S. Air Force. Its downrange stations include, among others, "auxiliary air force bases" at Jupiter, Florida; Grand Bahama Island; Eleuthera Island; San Salvador; Mayaguana Island; Grand Turk Island; Dominican Republic; Mayaguez, Puerto Rico; St. Lucia, Windward Islands; Fernando de Noronha Island, Brazil; and Ascencion Island.

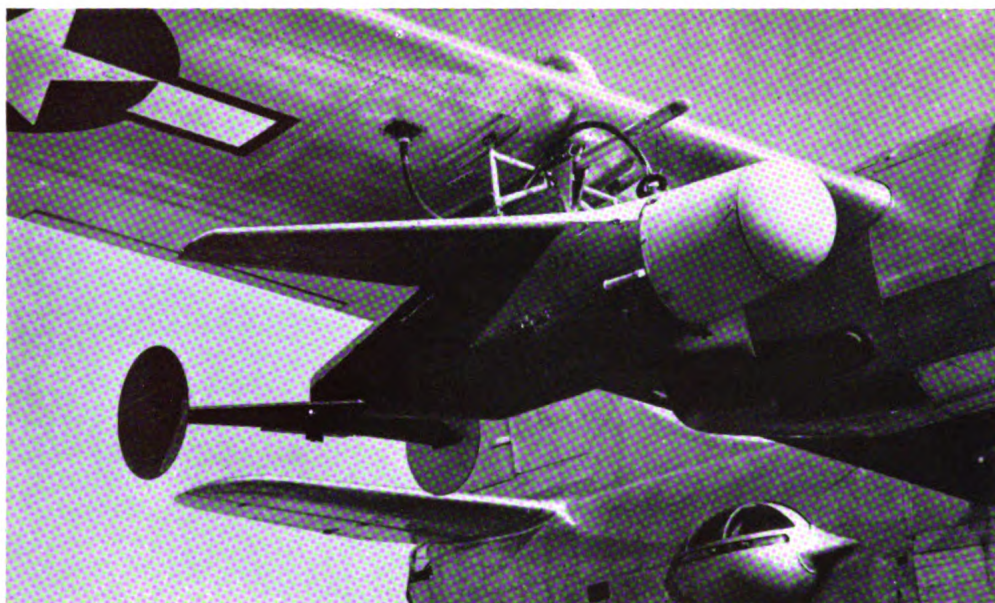
ATLAS. The SM-65 intercontinental ballistic missile (ICBM) of the U.S. Strategic Air Command. It carries a nuclear warhead, and has a range of 5500 nautical miles. It is launched vertically, and executes programmed roll to desired azimuth, and programmed pitch-over to desired flight attitude. Its length is 75 ft. (est.), and its diameter 10 ft. (est.). It has a stage-and-a-half airframe with liquid-propellant sustainer; with a thrust of about 60,000 lb. It has two liquid-propellant boosters in a flared-base skirt, each having 150,000 lb. thrust. Its launch weight is over 200,000 lb. Its airframe is made by Convair; its systems engineering is by Ramo-Wooldridge; its propulsion is by North American Rocketdyne; its guidance, by General Electric and Burroughs; its nose cone, by General Electric MOSD; its warhead, by the Atomic Energy Commission; its fuze, by Sandia Corp., and its power supply accessories, by American Machine & Foundry. It has a nonrigid tank section pressurized to provide structural rigidity. Its guidance is now radio-inertial, but is subsequently to be all-inertial. On Nov. 29, 1958, an Atlas ICBM completed the first successful flight over the 6,325-mile test range, described as the "full intercontinental range," from Cape Canaveral to the South Atlantic. (See **missile, guided**.) (See also illustration facing Page 27.)

ATMOSPHERE. The gaseous envelope surrounding any celestial object is known as the atmosphere of that object.

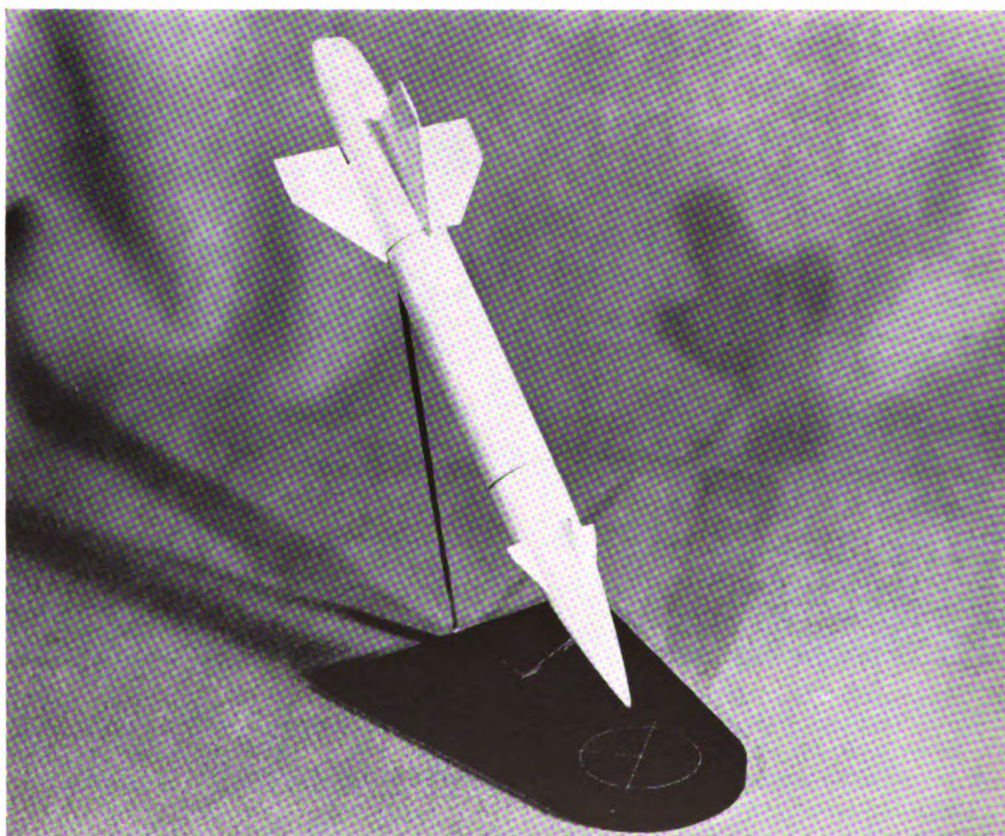
The general characteristics of the atmosphere of any object may be determined theoretically on the basis of the **kinetic theory of gases** and the mass, diameter, and surface temperature of the object. On the basis of this theory and the physical data regarding the various celestial objects, it is determined that the **stars** and **all planets**, except **Mercury**, should have atmospheres, while the **asteroids**,



An Air Force Boeing IM-99 BOMARC is shown leaving the launching pad during a test firing of this interceptor missile at the U.S. Air Force Missile Test Center, Patrick Air Force Base, Florida. The BOMARC is a long-range supersonic ground-to-air interceptor missile for air defense. (*U.S. Air Force Photograph*)



The BAT radar pilotless aircraft under the wing of a CONVAIR PB4Y "Privateer."
(U.S. Navy Photograph)



Model of the U.S. Navy's air-to-surface missile, the BULLPUP. The BULLPUP missile is designed to be launched by attack aircraft from any position outside the effective range of enemy high volume ground fire and to provide sufficient accuracy to destroy small targets without excessive sorties and expenditure of large quantities of bombs and rockets. (U.S. Navy Photograph)

moon, and the satellites of the other planets should be without appreciable gaseous envelopes. The conclusions, drawn from purely theoretical considerations, can be checked by a variety of observations, such as spectroscopic, **albedo**, **twilight arch**, etc., and the observational results are in close agreement with the theory.

The atmosphere of the earth in a thin layer. Three major regions make up the atmosphere—the troposphere, stratosphere and the ionosphere. (Sometimes a fourth region—the *chemosphere*—is also included.) There are also subdivisions of regions (e.g., *ecosphere*, *exosphere*, *mesosphere*, *ozonosphere*, *thermosphere*, etc.). (See Fig. 1.) The height of

easily compressed, its density being greatest near (or under) the earth's surface. The atmosphere is made up of a mixture of gases, its composition at sea level being given in the entry on **Air**.

Up to 230,000 feet small amounts of ozone, methane and nitrogen compounds have been detected (by high altitude research rockets). At sea level, 59°F (15°C), and 40° Latitude, barometric pressure is sufficient to support 29.92 inches of mercury. Air under these conditions weighs 0.07651 lbs/ft³.

Standard Atmosphere. The standard conditions of the air of the atmosphere are taken as: temperature = 59°F (at sea level); pressure = 14.7 psi (2116.8 psf) or 29.92 inches of

Fig. 1
REGIONS OF THE EARTH'S ATMOSPHERE

By Thermal Properties

Thermosphere
Mesopause
Mesosphere
Stratopause
Stratosphere
Tropopause
Troposphere

By Chemical Properties

Space
Mesosphere
Ionosphere
Ozonosphere
Chemosphere
Stratosphere
Troposphere
Ecosphere

By Homogeneity

Heterosphere
Homopause
Homosphere

By Electrical Properties

Ionosphere*
Neutropause
Neutrosphere

* F₂ Region 240 km-400 km
F₁ Region about 200 km
E₂ Region about 140 km
E₁ Region about 100 km
D Region about 60 km

the atmosphere varies from time to time, as is evidenced by the variations in barometric pressure occurring at the earth's surface. The variations cannot be set at any specific limit, since the trailing off of the tangible atmosphere with altitude is an asymptotic function approaching infinity as a limit. The limit of the atmosphere might be arbitrarily set at several thousand miles, although the atmosphere able to provide life-supporting gases is 20,000 feet or less. The earth's atmospheric gases, dust, and water vapor press on the planet's surface with a force equivalent to a layer of water 34 feet deep. At sea level this causes a pressure of approximately 14.7 pounds per square inch. The atmosphere is

mercury; density = 0.002378 lb-sec²/ft⁴ (slugs/ft³); kinematic viscosity = 0.0001566 ft²/sec; coefficient of viscosity = 37.24×10^{-8} lb-sec/ft². The standard air described above is an arbitrary one used in comparing the events of aerodynamics.

Standard International Atmosphere is the meteorological standard. It presumes the following conditions: at mean sea level a temperature of 15°C, a pressure of 1,013.2 millibars of mercury, a lapse rate of 6.5°C per kilometer from sea level to 11 kilometers and thereafter a constant temperature of -56.5°C. The Standard International Atmosphere is also an arbitrarily agreed upon set of values for meteorological comparisons.

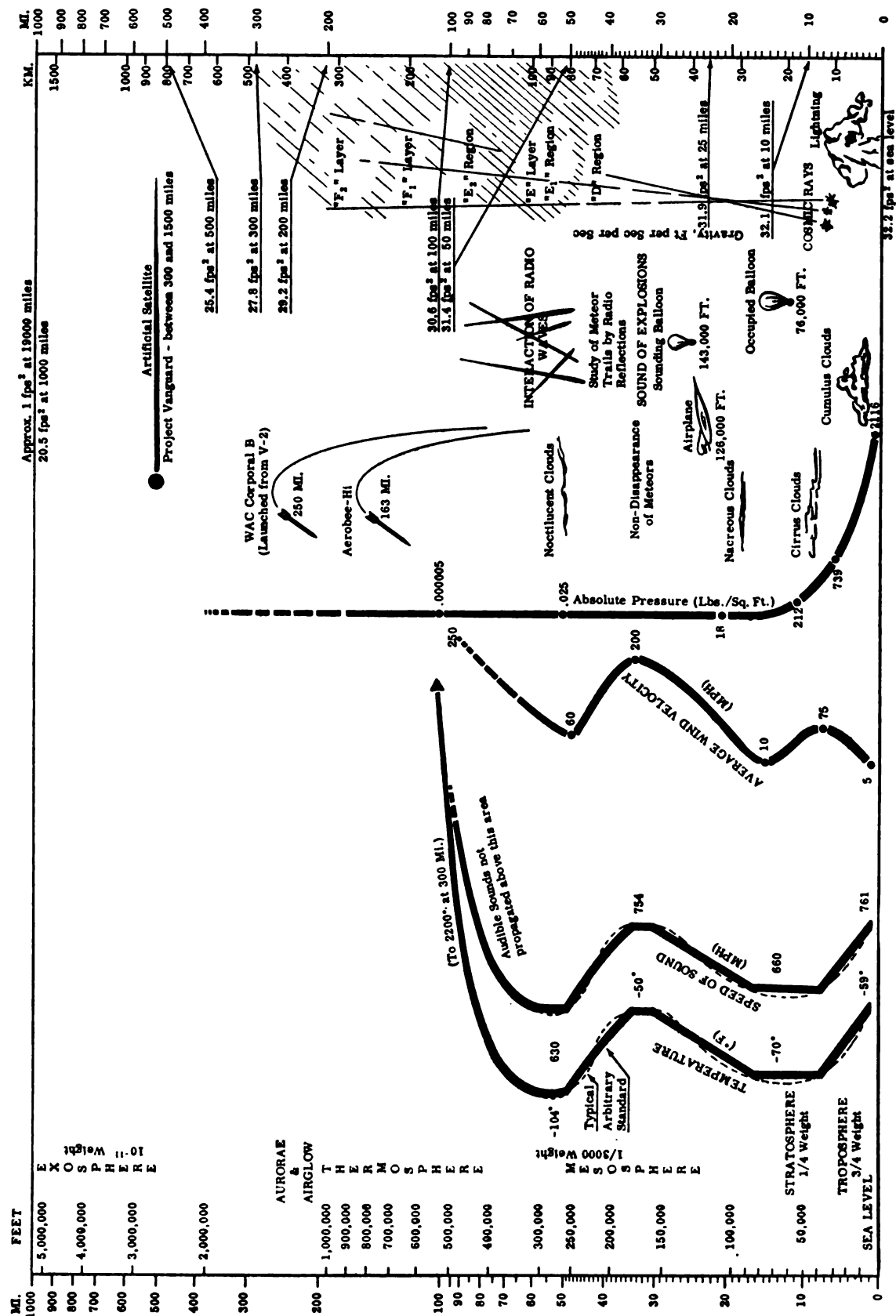


Fig. 2. Characteristics of the earth's atmosphere.

U.S. Standard Atmosphere was adopted in 1925 by all government departments for official use after being recommended by the National Advisory Committee for Aeronautics. (It is therefore frequently referred to as the *Standard NACA Atmosphere*.) The *U.S. Standard Atmosphere* is also an arbitrary and fictitious atmosphere. It assumes that the air is a dry perfect gas with a ground level temperature of 15°C (59°F), a temperature gradient in the troposphere of 0.0065°C/meter or 0.003566°F/ft., and that the stratosphere temperature (11 kilometers to 100 kilometers) is -56°C (-67°F). The sea level pressure is 29.92 inches (760 mm) of mercury. All these measurements are assumed at 40° Latitude. The temperature in the *atmosphere* drops ap-

proximately 1.98°C for each 1000 feet increase of altitude until 35,332 feet is reached after which the temperature remains at a constant -56°C. (The meteorological average temperature decrease is calculated to be 0.5°C per 100 meters (or about 1°F per 300 feet.) This is 1.52°C for each 1000 feet increase in altitude. In spite of all the "standards" none reproduce the atmosphere exactly since it always changes.

The *International Civil Aeronautics Organization (ICAO) standard atmosphere* was approved in 1952. This covered to 60,000 feet (approximately 20 kilometers). The 1952 ICAO *atmosphere* changed the previous standard (NACA Standard Atmosphere of 1925). In 1956, the U.S. Weather Bureau and the

NACA STANDARD ATMOSPHERE

An arbitrary and fictitious atmosphere established for comparison purposes. At sea level, a pressure of 29.92 inches (760 mm) of mercury, a temperature of 50°F (15°C), with the air perfectly dry is the beginning assumption. This state is considered to be the average condition prevailing at 40° North latitude. The temperature in the *standard atmosphere* decreases with altitude. At 40°N latitude it drops approximately 1.98°C for each 1000 feet increase in altitude until 35,332 feet is reached. After this the temperature remains at -55°C. The *meteorological average* temperature decrease is calculated at 0.5°C per 100 meters increase in altitude (or about 1°F per 300 feet). This amounts to 1.52°C for each 1000 feet increase in altitude. The following table gives the values of various parameters as established for the Standard Atmosphere:

ALTITUDE (Feet)	TEMPERATURE (°F)	PRESSURE				DENSITY (Slugs/ft ³)
		<i>psia</i>	<i>inches mercury</i>	<i>milli- bars</i>	<i>atmos- pheres</i>	
0	59.0	14.7	29.92	1013	1.0	0.002378
2,500	50	13.4	27.3	930	.910	
5,000	41.2	12.2	24.89	850	.850	0.002047
7,500	32	11.11	22.4	750	.750	
10,000	23.3	10.11	20.58	699	.688	0.001755
15,000	5.5	8.29	16.88	571.62	.564	0.001496
20,000	-12.3	6.75	13.75	465.63	.459	0.001268
25,000	-30	5.45	11.1	375.89	.371	0.001068
30,000	-48	4.36	8.88	300.0	.295	0.000893
35,000	-65.8	3.46	7.00	238.4	.235	0.000740
40,000	-67	2.72	5.54	187.61	.185	0.000585
45,000	-67	2.14	4.36	147.65	.146	0.000462
50,000	-67	1.68	3.44	116.15	.115	0.000364
55,000	-67	1.32	2.71	91.43	.091	0.000287
60,000	-67	1.04	2.13	72.13	.071	0.000227
65,000	-67	.83	1.68	56.89	.056	0.000179
70,000	-67	.65				0.000141
80,000	-67	.41				0.000088
90,000	-67	.26				0.000055
100,000	-67	.16				0.000035

ICAO EXTENSION OF NACA STANDARD ATMOSPHERE

In 1956, the International Civil Aeronautics Organization approved an extension to the standard atmosphere as follows:

$H(m')$	$Z(m')$	$L(^{\circ}K/m')$	$T_M(^{\circ}K)$	$T(^{\circ}K)$	$M(gm/mole)$	$P(mb)$
0	0		288.16	288.16	28.966	1.01325×10^3
		-0.0065				
11,000	11,019		216.66	216.66	28.966	2.2632×10^2
		0.000				
20,000	20,063		216.66	216.66	28.966	5.4748×10^1
		0.00				
25,000	25,099		216.66	216.66	28.966	2.4886×10^1
		0.0030				
32,000	32,162		237.66	237.66	28.966	8.6776×10^0
		0.0030				
47,000	47,350		282.66	282.66	28.966	1.2044×10^0
		0.000				
53,000	53,446		282.66	282.66	28.966	5.832×10^{-1}
		-0.0039				
75,000	75,895		196.86	196.86	28.966	2.4521×10^{-2}
		0.000				
90,000	91,294		196.86	196.86	28.966	1.8154×10^{-3}
		0.0035				
126,000	128,548		322.86	278.88	25.02	1.4510×10^{-5}
		0.0100				
175,000	179,954		812.86	686.13	24.45	6.1895×10^{-7}
		0.0058				
300,000	314,859		1537.86	1024.67	19.30	1.4473×10^{-8}

Where H = altitude in geopotential meters, Z = altitude in geometric meters, L = temperature lapse rate in $^{\circ}K$ per geopotential meter, T_M = molecular scale temperature in $^{\circ}K$, T = real kinetic temperature in $^{\circ}K$, M = molecular weight in grams per mole, and P = pressure in millibars.

Geophysics Research Directorate of the Air Force Cambridge Research Center adopted an extension to the 20 kilometer standard to 320 kilometers. See tables below for both the NACA Standard Atmosphere and the ICAO extension.

Atmospheric Lapse Rate. The variance of atmospheric temperature with altitude. The temperatures of the atmosphere have been measured by the following methods to develop the lapse rate: 0-30 km—balloons; 30-35 km—solar spectroscopy; 30-35 km sound propagation; 70-120 km—auroral spectra. (See also *Temperature*.)

Upper atmosphere. The region above 30 kilometers (about 20 miles). Here the temperature begins to increase with altitude after having progressively decreased through the troposphere and remained constant through the lower stratosphere. It is actually the

upper portion of the stratosphere. At 31 miles altitude the "air" temperature has increased from $-67^{\circ}F$ to $+170^{\circ}F$. Beyond this altitude the temperature appears to remain constant for some miles and then drops again. At 50 miles the temperature has been measured at $-27^{\circ}F$. Theoretical computations show the temperature at 200 miles to be $1,500^{\circ}F$. It is thought that this increase continues upward to $20,000^{\circ}F$ or more. However, all these high temperatures are not meaningful temperatures but are concerned with the kinetic energy of the movement of the few molecules involved. Moreover, data from the Pioneer probe (See **Thor Able I**) gave materially lower temperature readings. (See Fig. 2.) The Geophysics Research Directorate of the U.S. Air Force Cambridge Research Center distinguishes atmospheric regions on the basis of their changes in tem-

REGIONS OF THE UPPER ATMOSPHERE

Name	Distance from surface of earth	Lapse Rate	Temperature	Mean free path	Phenomena
Chemosphere	32-80 km	+2 to 4°C/km	20°F to 100°F	0.5 cm	Noctilucent clouds Separation of gases Photochemical zone
Chemopause	80 km	+2 to 8°C/km	2000°F	500 m	Aurorae
Ionosphere	80-400 km	+2	(?)		E, F ₁ and F ₂ in day E and F at night
Ionopause	400 km				
Mesosphere Mesopause		Decrease (?)	High	10 ³ m	Highest aurorae High electron density
Exosphere	1000 km and beyond			1 km or more	Beginning of space

perature gradients (i.e., lapse rates). Their classification is as follows:

Troposphere (0-10 mi) = 6.5°C/km

Tropopause

Stratosphere (10-40 mi) = constant 216.66°K (zero lapse rate)

Stratopause

Chemosphere (about 50 mi) = 20°F to 100°F (turbulent region)

Chemopause

Ionosphere (40-400 mi) = increase in temperature to unknown values

ATMOSPHERE, CIRCULATION OF THE.

When averaged over long periods of time, local and small-scale irregularities in the atmosphere's motions disappear and a generalized pattern of winds is manifest. There are five latitudinal belts in each hemisphere into which generalized winds can be classified:

(1) The doldrum belt which extends roughly from the equator to 10 or 15° north and south is a belt of light variable winds.

(2) The trade wind belt extends from 10 or 15° north and south to approximately 30° north and south. Trade winds blow from the northeast to east-northeast in the northern hemisphere and from the southeast to east-southeast in the southern hemisphere and are known respectively as the northeast trades and the southeast trades.

(3) A narrow and drifting belt of light variable winds extends about the earth at approximately 30° north and south. This belt is known as the horse latitudes.

(4) Westerly winds with a slight compo-

nent from the south blow in a relatively wide band from approximately 30° north and south to 60 or 70° north and south. They are known as the prevailing westerlies but in the southern hemisphere are more commonly known as the roaring Forties because of their stronger and more steady character.

(5) The polar area winds tend to blow anticyclonically with an easterly component over each region. (See also **Winds**.)

ATMOSPHERE, MODEL. A hypothetical atmosphere based on the temperature function by layer. Each layer has a temperature gradient linear with geopotential altitude but whose first derivatives are discontinuous at the intersection of the layers.

ATMOSPHERE, STANDARD. (1) A unit of pressure, defined as the pressure exerted by a column of mercury 760 mm high, having a density of 13.5951 gm cm⁻³ and subject to gravitational attraction of 980.665 dyne gm⁻¹, which is equal to 1.013250 × 10⁶ dyne cm⁻². (2) In meteorology, an atmosphere having a sea-level pressure of 1.013250 × 10⁶ dyne cm⁻² (1,013.25 millibars); a sea-level temperature of 15°C; and a lapse-rate of 6.5°C up to 11 km. (See more detailed discussion in entry on **atmosphere**.)

ATMOSPHERIC BRAKING. A technique of re-entry aerodynamics in which the re-entering body is slowed in velocity by atmospheric drag. The technique involves entering the atmosphere at a shallow angle, decelerating until aerodynamic heating becomes serious,

pulling up out of the atmosphere to cool off, then entering again and again, ever deeper until the successful deceleration is made and flight within the atmosphere is possible.

ATMOSPHERIC DUCT. An atmospheric layer which conducts radio-frequency waves in the same manner as a true waveguide under certain conditions of temperature and humidity. Attenuation at certain frequencies is quite low and transmissions may be received at points far outside the usual reception area.

ATMOSPHERIC INSTABILITY. The condition in the atmosphere in which vertical movement is prevalent. (See **atmospheric stability**.)

ATMOSPHERIC INTERFERENCE (SPHERICS). The interference caused radio reception by natural electric disturbances in the atmosphere.

ATMOSPHERIC INVERSION. The condition in which the temperature of the atmosphere increases with height, contrary to the usual state of affairs.

ATMOSPHERIC PRESSURE. The pressure upon an object, such as the human body, in the **atmosphere** due to the weight of air above it.

ATMOSPHERIC RADIO WAVE. A radio wave that is propagated by reflections in the atmosphere. It may include either or both of the components, **ionospheric wave** and **tropospheric wave**.

ATMOSPHERIC REFRACTION. Refraction of light from a distant point by the atmosphere, caused by its passing obliquely through varying air densities.

ATMOSPHERIC SHELL. One of the regions of the **atmosphere**, e.g., stratosphere, troposphere, etc., or the entire air envelope as a whole.

ATMOSPHERIC SOUND REFRACTION, CONVECTIVE. The bending of sound rays in the atmosphere due to a gradient in the wind velocity.

ATMOSPHERIC SOUND REFRACTION, TEMPERATURE. The bending of sound rays in the atmosphere due to a temperature

gradient (and hence a gradient in the sound velocity).

ATMOSPHERIC STABILITY, INSTABILITY, AND EQUILIBRIUM. Everywhere that air is in motion some vertical perturbations are present. Isolated parcels and currents of air are thus started upward or downward in a layer of surrounding air. The action of the environment on the displaced parcels is a measure of the stability or instability of the air. If the parcel is forced back to its original position, the air is stable and does not favor vertical motions; if the parcel is accelerated in its vertical movement, then the air is unstable and favors vertical motions; if the parcel comes to rest at a new position, neither rising nor falling, then the air is in an equilibrium state.

ATMOSPHERICS. (1) Disturbances to radio transmission caused by the static electricity in the atmosphere, i.e., "static." (See also **strays**.) (2) Atmospherics is also a term sometimes applied to the peculiar phenomena associated with the 11-year long sun spot cycles. During those years the sun spot activity is greatest (1956-1958 are bad years), extremely long range radio reception is possible by means of reflections from the greatly intensified ionosphere. Decimetric waves (the amateur band), are extremely susceptible to multiple reflections and these can sometimes bounce over the whole hemisphere, enabling weak power stations to be heard loud and clear over extremely long distances. (See also **Aurora** and **Sun Spots**.)

ATOM. The smallest particle of an **element** which can enter into chemical **combination**. All chemical compounds are formed of atoms, the difference between compounds being attributable to the nature, number, and arrangement of their constituent atoms. For current views of structure, see **atomic structure**.

ATOM DISINTEGRATION. The **emission** by an atomic nucleus of a particle or particles, or larger fragments, and radiations, resulting in the formation of new atomic species, differing from the original in mass, atomic number, or energy or in more than one of those properties. Disintegration may occur naturally, as in the case of the radioactive **elements**, or may be produced artificially, by bombardment with particles or radiations.

ATOM, IONIZED. An ion, which is an atom that has acquired an electric charge by gain or loss of **electrons** surrounding its **nucleus**.

ATOMIC CLOCK. A very accurate source of frequency (or time) which depends upon the invariant nuclear resonance of certain elements such as cesium when subjected to a RF electromagnetic field. Accuracies of one part in 10^{12} are achievable. (See also **Atomichron**.)

ATOMIC DEVICE. Any device that makes use of nuclear fissionable, radioactive material, especially on atomic bomb, shell, or other atomic missile.

ATOMIC DISTANCE. The average distance separating the centers of two atoms.

ATOMIC ENERGY. (1) The constitutive internal energy of the atom, which would be absorbed when the atom is formed from its constituent particles, and released when it is broken up into them. This is identical with the **binding energy** and is proportional to the **mass defect**. (2) Energy released as the result of the disintegration of atomic nuclei, particularly in large scale processes.

ATOMIC HYDROGEN. The dissociation of the hydrogen molecule into atoms is a highly endothermic reaction, that is, it absorbs large quantities of energy, such as are available in the electric arc. This energy is released when the atoms recombine to form molecules, and it is increased if the hydrogen molecules are then burned to form water. While all three processes—dissociation, recombination and burning occur in the oxy-hydrogen torch, obviously if atomic hydrogen were to be used as a rocket fuel, its maximum energy could be realized only by dissociating the molecules in advance, and storing the atomic hydrogen on the space ship. As yet methods for “stabilizing” atomic hydrogen have not been discovered, at any rate, under conditions which are practicable on a space ship; therefore it is not a currently-available fuel. (See also **free radicals**.)

ATOMIC MASS. The mass of a neutral atom of a nuclide. It is usually expressed in terms of the physical scale of atomic masses, that is, in atomic mass units (amu).

ATOMIC NUMBER. Atomic structure.

ATOMIC STRUCTURE. In its internal structure the atom consists of a nucleus that has a positive electric charge, and in which most of the mass of the atom is concentrated. Moving about this nucleus are electrons, sufficient in number so that their total negative charge is equal to the positive charge on the nucleus. For example, atoms of the element hydrogen have in their normal state a single electron moving about a nucleus which has a positive charge equal to the negative charge on the electron. An atom of the element helium has two electrons moving about its nucleus, which, in turn, has a positive charge equal to twice one electronic charge. An atom of the element lithium has three electrons, and a nuclear charge equal in amount to three times the electronic charge—or, in other words, equal to three times the charge on the nucleus of the hydrogen atom. One basis for the classification of atoms is by numbers which correspond to the number by which the charge on the hydrogen nucleus must be multiplied to equal the nuclear charge of the atom in question. These numbers range from one (for hydrogen) to 92 (for uranium) and to still higher for the transuranic elements. These numbers are called **atomic numbers** and are designated by the symbol Z . They are important because they determine the chemical behavior of the atoms. For while atoms may differ in other properties than nuclear charge, such as nuclear mass and nuclear stability, all atoms having the same nuclear charge exhibit the same chemical properties regardless of the differences they may exhibit in other properties. A working definition of this term chemical properties is the behavior of atoms of different elements in their union and their separation. One reason for the correspondence between this behavior and the atomic number is that combinations between atoms are formed by electrical forces between their electrons which, as stated above, in normal atoms are the same in number as the atomic number of the atom.

ATOMIC WEIGHT. The weight of an atom of any element, the weight of the oxygen atom being taken as 16. The atomic weight is also called the equivalent weight or the relative weight. Since many elements, as they commonly occur in nature, are mixtures of **isotopes**, the accepted values of their atomic weights are in reality mean values of the

isotopic atomic weights of the various isotopes present. The atomic weight, as defined above, is often called the "chemical atomic weight," taking as its basis a value of 16 for ordinary atmospheric oxygen. Since atmospheric oxygen consists of a mixture of 3 different isotopes, a "physical atomic weight" scale has been established which assigns to the lowest mass isotope the value 16.

ATOMICRON. An instrument using atomic principles to control radio frequency equipment. A "cesium clock" is an example of an atomichron. These employ the natural resonant frequencies of atomic structure (electrons) as a reference for frequency regulation. Extremely good accuracies (10^{-12}) can be obtained for a wide range of frequencies obtained by the application of "kits" to produce the desired frequency from the basic atomic frequency.

ATOMIZATION. The breaking-up of a liquid into small droplets, usually in a high-speed jet or film.

ATR. Anti-transmit-receive switch; commonly used in radars to inactivate the receiver when transmitting.

ATRAN. An abbreviation standing for Automatic Terrain Recognition And Navigation. It is a system of missile guidance in which photographs of the desired track are compared with radar pictures of the actual track to secure steering information.

ATRC. Air Training Command; Scott Air Force Base; Belleville, Illinois.

ATTRITION. Gradual reduction in numbers, usually owing to enemy action.

ATTACHED SHOCK WAVE (OR ATTACHED SHOCK). An oblique or conical shock wave that is in contact with the sharp leading edge or the nose of a body in a supersonic flow field.

ATTACHMENT. In U.S. Air Force terminology, a supplementary device composed of a part and/or assemblies which, when fastened to or mounted on an end item, varies or extends the basic function of the item to which attached. (See also **Accessory**, and **Assembly**.)

ATTENUATION. In its most general sense, attenuation is reduction in concentration, density or effectiveness. In radiation theory, attenuation is used to express the reduction in flux density, or power per unit area, with distance from the source; the reduction being due to absorption and/or scattering. It is thus a reduction in amplitude or energy of an electromagnetic signal. (See also **Transmission Line**.)

The absorption of electromagnetic waves in an isotopic, gaseous medium may be obtained by assuming a uniform distribution.

Absorption loss, db/meter = $-8.68\omega\mu^{\frac{1}{2}}k$ where k , the index of absorption is determined from

$$k^2 = \frac{1}{2} \left[-\left(\epsilon - \frac{4\pi\sigma_i}{\omega} \right) + \sqrt{\left(\epsilon - \frac{4\pi\sigma_i}{\omega} \right)^2 + \left(\frac{4\pi\sigma_r}{\omega} \right)^2} \right]$$

and the relative phase shift for the same signal may be expressed as: Relative phase shift = $\omega\mu^{\frac{1}{2}}n$ (in rad/sec).

$$n^2 = \frac{1}{2} \left[\left(\epsilon - \frac{4\pi\sigma_i}{\omega} \right) + \sqrt{\left(\epsilon - \frac{4\pi\sigma_i}{\omega} \right)^2 + \left(\frac{4\pi\sigma_r}{\omega} \right)^2} \right]$$

and where μ is the permeability of the medium, and ϵ is the dielectric constant of the medium.

ATTENUATION BAND. Rejection band.

ATTENUATION CONSTANT. For a traveling plane wave at a given frequency, the rate of exponential decrease of the amplitude of a field component (or of the voltage or current) in the direction of propagation, in **nepers** or **decibels** per unit length.

ATTENUATION FACTOR. (1) A measure of the opacity of a layer of material for radiation traversing it. It is equal to I_0/I , in which I_0 and I are the intensities of the incident and emergent radiation, respectively. In the usual sense of exponential absorption

$$I = I_0 e^{-\mu x}$$

where x is the thickness of the material and μ is the **absorption coefficient**. (2) A meaning similar to that in (1) is current in electrical circuit applications, where the attenuation factor is the ratio of the input current to the

output current of a line or network. (3) For acoustic attenuation factor, see **absorption coefficient**.

ATTENUATION, SIDEBAND. That form of **attenuation** in which the transmitted relative amplitude of some component(s) of a **modulated signal** (excluding the **carrier**) is smaller than that produced by the **modulation** process.

ATTENUATION, VOLTAGE (TRANSDUCER). The ratio of the magnitude of the voltage across the input of the **transducer** to the magnitude of the voltage delivered to a specified load impedance connected to the transducer. If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. By an extension of the term "decibel," this attenuation is often expressed in decibels by multiplying its common logarithm by 20.

ATTENUATOR. A network used to reduce electromagnetic wave amplitudes without otherwise distorting their character or appearance. It is designed so the **impedance** of the attenuator will match the impedance of the circuit to which it is connected, often being connected between two circuits of different impedance and serving as a matching network as well as an attenuator. It is distinguished from a simple resistance in that the impedance of an attenuator does not change for various values of its attenuation. It is a valuable unit in making many laboratory tests on communications equipment where it is used to adjust the outputs of two pieces of apparatus or for two different conditions so the relative merits may be determined from the attenuator setting. In much communication work it is desirable to transmit power at a higher level than will be used in order to overcome circuit noises, and then to reduce it to the proper value at the receiving end by a pad. It is usually calibrated in **decibels** and thus indicates the attenuation introduced by it. In waveguides a strip of dielectric material introduced into the open channel will alter the velocity of the wave and so cause a phase change. An adjustable vane inserted through a slit in a waveguide can be used to give a variable attenuation.

ATTENUATOR, CHIMNEY. One form of coaxial-line attenuator which received its name from the appearance of the stub lines.

ATTENUATOR, COAXIAL LINE. An attenuator for use in a coaxial line. It may be fixed or variable.

ATTENUATOR, FLAP OR FIN. A waveguide attenuator in which a fin or flap of conducting material is moved into the guide in such a manner as to cause power absorption.

ATTENUATOR, TRANSVERSE FILM. An attenuator consisting of a conducting film placed transverse to the axis of a waveguide.

ATTITUDE. The aspect that an aircraft or missile presents at any given moment with reference to some established coordinate system. For example, attitude can be described by inclinations about the three axes of the missile, that is, by pitch, yaw, and roll.

ATTITUDE CONTROL. A control system or mechanism, as an automatic pilot, that puts or keeps an aircraft or missile in a desired attitude. (See also **Control, Guidance and Path Control**.)

ATTRACTION, ELECTRICAL. The force between electric charges of opposite sign, having a magnitude given by the **Coulomb Law**.

ATTRACTION, GRAVITATIONAL. According to the **Newton law of universal gravitation**, every mass in the universe attracts every other mass with a force directly proportional to the product of the masses and inversely proportional to the distance between their centers of mass. This attraction is illustrated in the solar system by the attraction exerted by the sun upon the planets and by the individual planets upon each other.

ATTRACTION, MAGNETIC. A force exerted by a magnetized body upon another capable of **magnetization**, as of an iron magnet upon a piece of iron. The force between two magnets may be an attraction or a repulsion, depending upon orientation.

Au. Gold.

AUDIBILITY, LIMITS OF. The thresholds of hearing: the minimum effective sound pressure that can be heard at a specified frequency forms the lower limit (minimum audibility or

threshold pressure); the minimum effective sound pressure that causes feeling or pain in the ear forms the upper limit (threshold of feeling).

AUDIO. Pertaining to sound or hearing. The word "audio" may be used as a modifier to indicate a device or system intended to operate at **audio frequencies**.

AUDIO AMPLIFIER. An amplifying circuit designed to boost the amplitudes of frequencies in the **audio** range. (See **Amplifier**.)

AUDIO FREQUENCY. A frequency corresponding to a normally audible sound wave. Audio frequencies range between 15 and 15,000 cycles per second.

AUDIO-FREQUENCY HARMONIC DISTORTION. The generation in a system of integral multiples of a single audio-frequency input signal.

AUDIO-FREQUENCY PEAK LIMITER. A circuit used in an audio-frequency system to cut off peaks that exceed a predetermined value.

AUGEND. In arithmetic the number to which another number is added. (The number added is called the **addend**.) (See **Binary Arithmetic**.)

AUGMENTED THRUST RATIO. The ratio of thrust obtained by a turbojet with its afterburner operating to that without. It is given by the relationship:

$$F_a/F = \frac{V_{ja} - V}{V_j - V} = \frac{\sqrt{T_{6a}/T_6} - \nu}{1 - \nu},$$

where F_a is the thrust with afterburner operating, F is the thrust without, V_{ja} is the exhaust jet velocity with afterburner operating, V_j is the exhaust jet velocity without, V is the inlet velocity (velocity of vehicle), T_{6a} is the exit temperature ($^{\circ}\text{R}$) with afterburner operating, T_6 is the exit temperature without, and ν is the ratio V/V_j .

AUGMENTOR. A device for increasing the mechanical efficiency of a machine. (See **Thrust Augmentor**.)

AUM. Air-to-Underwater Missile. (See **model designation**; **missile**, **air-to-ground**.)

AUM-N-2. A U.S. Navy (BuOrd) air-to-underwater missile made by the Fairchild Guided Missile Division. Also called **Petrel**.

AURAL NULL. A condition of minimum or no aural signal being received over a radio-receiving set using a directional antenna.

AURIGA. (The charioteer.) This **constellation** is best known because it contains the bright star **Capella** (the she-goat) and her kids. The kids are three fainter stars forming to the naked eye a small triangle and which always serve to distinguish Capella from other bright stars on a clear night. Capella is a bright star, yellowish in appearance, and of the same **spectral type** as our sun. The star, however, is so much larger than our sun that, in spite of its great distance (49 **light years**), it appears as 1st **magnitude**, whereas the sun at the same distance would be 6th magnitude, or barely visible to the naked eye on a clear moonless night. Capella is a spectroscopic **binary** with a period of 104 days.

AURORA AUSTRALIS. Discussed under **Aurora borealis**.

AURORA BOREALIS. This well-known phenomenon of the upper **atmosphere** in middle and higher latitudes is now recognized as an electrical discharge in the ionized air, exhibiting, as it does, characteristic **spectrum** lines of the rarer atmospheric gases. The aurora appears in a variety of aspects, sometimes as a faintly luminous streak or arch, sometimes as bright streamers like a searchlight beam, sometimes resembling folds of a luminous curtain waved by the wind. Its intensity is greatest in an indefinite region apparently encircling the magnetic pole, toward which the streamers seem to converge. The occurrence of the phenomenon is intermittent, but with distinct evidence of several periodicities. **Sunspot** maxima, with their 11-year period, are always accompanied by maxima in the frequency and brightness of the aurorae. There are also smaller auroral maxima in March and October each year. Aurorae, like sunspots, are practically always attended by disturbances of **terrestrial magnetism**. A corresponding display in the southern hemisphere is called *aurora australis*.

AURORAL PARTICLES. High speed electrons, protons etc. emanating from the sun

and entering the upper atmosphere near the poles to produce luminous aurorae.

AUSTENITE. In metallurgy, originally a solid solution of carbon in gamma iron. Now it includes all solid solutions based on gamma iron. To austenitize means to form this stable mixture by heating the steel.

AUTOCOLLIMATOR. (1) A device by which a lens makes diverging light from a slit parallel, and then after the parallel light has passed through a prism to a mirror and been reflected back through the prism, the same lens brings the light to a focus at an exit slit. (2) A telescope provided with a reticle so graduated that angles subtended by distant objects may be read directly. (3) A convex mirror placed at the focus of the principal mirror of a reflecting telescope and of such curvature that the light after reflection leaves the telescope as a parallel beam.

AUTODYNE DETECTOR. Beatnote detector.

AUTOELECTRIC EFFECT. The emission of electrons from a cold cathode due to the application of an intense electric field at its surface.

AUTOGYRO. A type of aircraft in which lift is supplied by free rotating vanes instead of fixed wings. Rotation of the vanes is induced as the aircraft moves forward from the thrust of a separate propeller. The helicopter differs from the autogyro in that the helicopter's vanes are powered.

AUTOMATIC CELESTIAL NAVIGATION. A system of missile guidance involving the use of regular celestial navigation techniques but without the use of human links. Such an automatic system would require the following general components: automatic star tracker and telescopic detector; stable platform with an earth reference (i.e., it must be a programmed device to tilt according to travel of the missile in order to compensate for systematic earth reference errors such as deviation of the vertical); computer and servo control system to execute the flight commands. Such a guidance system is normally applied to long-range aerodynamically supported missiles.

AUTOMATIC CONTROL SYSTEM. Any operable combination of one or more automa-

tic controllers connected in closed loops with one or more processes.

AUTOMATIC CONTROLLER. A device which measures the value of a variable quantity or condition, and operates to correct or limit deviation of this measured value from a selected reference. It includes both the measuring means and the controlling means.

AUTOMATIC FREQUENCY CONTROL. A circuit arrangement whereby the frequency of an oscillator is automatically maintained within specified limits. It is commonly effected by a circuit which generates a low frequency correction to maintain the intermediate frequency at its correct value (i.e., frequency-modulating the local oscillator at an audio rate to provide a carrier).

AUTOMATIC GAIN CONTROL (AGC). A means of accomplishing regulation of the magnitude of the output signal level of a system. It is commonly effected by a circuit which automatically varies the amplification of another circuit inversely with the input signal strength so that the output signal amplitude is always constant. It is abbreviated AGC.

AUTOMATIC PILOT. Autopilot.

AUTOMATIC TERRAIN RECOGNITION AND NAVIGATION SYSTEM. Atran.

AUTOMATIC TRACKING. Tracking in which a servomechanism keeps the radar beam trained on the target, by utilizing the echo signal from the target.

AUTOMATIC VOLUME CONTROL. The automatic regulation of the amplitude (e.g., loudness of a signal) even though the input signals vary in strength. Automatic volume control is actually automatic gain control operating in the audio range.

AUTOMATION. The technique of improving human productivity in the processing of materials, energy and information by utilizing in various degrees, elements of automatic control and of automatically executed product programming.

AUTONETICS. The name of a division of North American Aviation Incorporated. The coined word refers to that part of the company building guidance, flight control, arma-

ment control, flight test and other electromechanical devices.

AUTOPILOT. An automatic control mechanism for keeping a missile in level flight and on course or causing it to maneuver. It is responsible for the **attitude** control of the missile. It is a servosystem specially designed for each missile application since each missile's response is different and is a critical feature of the autopilot-servolink. Autopilots need inputs of missile angular error displacement as determined from gyro pick-offs and inputs of rates of change of the angular error displacement (in order to prevent oscillations in the autopilot). An automatic control device for maintaining a missile on a certain course and attitude makes use of gyroscopes for reference and servomechanism loops for control, basing their control actions upon the detected errors from the gyro references. (See figure.) The autopilot may or may not have equipment to detect non-predictable errors during flight and to correct for these. In most missile applications, the autopilot is not the only controlling device aboard, but merely works during one phase of the guidance cycle or does some portion of the overall guidance work. An autopilot alone is not sufficiently inclusive in its control ability to provide an "intelligent" flight from launch to impact; it merely "keeps the missile flying" but does not provide the "commands."

AUTOPILOT AMPLIFIER. Amplifier, autopilot.

names when manufactured by other companies. As a general word, Selsyn is preferred in the United States. It is an electrical **servo** for producing precise rotational positions.

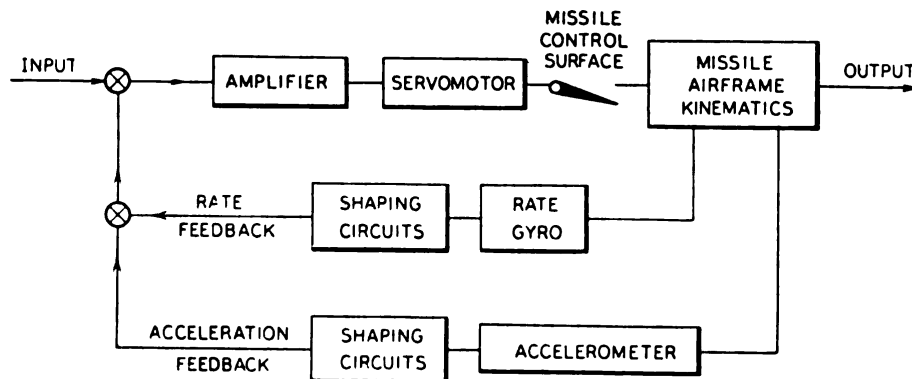
AUTOTRACK. Radar, Lockon.

AUTOTRANSFORMER. A transformer in which one coil serves as both primary and secondary.

AUTUMNAL EQUINOX. The point where the sun appears to cross the **celestial equator** from north to south.

AUXILIARY POWER SUPPLY UNIT. In a missile a separate and special generator, usually of the gas turbine variety, used for the production of on-board power. It can be either a solid propellant or liquid propellant gas generator that is duct-connected to a turbine which in turn is connected by a shaft to an electric generator. A typical small unit measuring 13 x 10 x 7 inches, weighing 29 pounds, can provide electrical, mechanical or hydraulic power in the amount of 650 watts. This particular type uses chemical rocket **propellants** (in a fuel-rich mixture) to turn a turbogenerator at 24,000 rpm.

AVAILABLE POWER. (1) Of a linear source of electric energy, the quotient of the mean square of the open-circuit terminal voltage of the source, divided by four times the resistive component of the internal **impedance** of the source. The available power would be delivered to a load impedance that is the con-



Simplified block diagram of autopilot.

AUTOSYN. A commercial trade name (Bendix-Marine) derived from the words: AUTOMATIC and SYNchronous. This device is also called Synchro, Selsyn, or by several other

jugate of the internal impedance of the source, and is the maximum power that can be delivered by that source.

(2) From a **generator** or an electric trans-

ducer, the power that would be delivered to the output external termination of the generator or transducer if the **admittance** of the external termination were the conjugate of the output driving-point admittance of the generator or transducer.

(3) The available power of a sound field, with respect to a given object placed in it, is the power which would be abstracted from the acoustic medium by an ideal transducer having the same dimensions and the same orientation as the given object.

AVALANCHE. A term used in counter technology to describe the process which is essentially a cascade multiplication of ions. In this process, an ion produces another ion by **collision**, and the new and original ions produce still others by further collisions, resulting finally in an "avalanche" of ions (or electrons). The terms "cumulative ionization" and "cascade" are also used to describe this process.

AVERAGE. Defined for a quantity Q by

$$\bar{Q} = \frac{\sum w(a_1, \dots, a_n) Q(a_1, \dots, a_n)}{\sum w(a_1, \dots, a_n)}$$

where w is the **weighting function**. The ordinary average is obtained by taking $w = 1$ so

$$\bar{Q} = \frac{\sum Q(a_1, \dots, a_n)}{n}$$

When Q and w are continuous,

$$\bar{Q} = \frac{\int_{\tau} w(x_1, \dots, x_n) Q(x_1, \dots, x_n) dx_1 \dots dx_n}{\int_{\tau} w(x_1, \dots, x_n) dx_1 \dots dx_n}$$

where τ is the domain of definition of Q and w .

AVERAGE DEVIATION. In statistics the average deviation (A.D.) of a number of like quantities X_j is the average of the absolute departures of their individual values from their mean

$$\text{A.D.} = \frac{\sum_{j=1}^n |X_j - \bar{X}|}{n},$$

where the mean

$$\bar{X} = \frac{\sum_{j=1}^n X_j}{n}$$

The A.D. is a measure of the expected departure of any single observation of a series from the "true" value which would be obtained by the averaging of an infinite series of observations. The average deviation of the mean (a.d.) is

$$\text{a.d.} = \text{A.D.} / \sqrt{n-1}$$

A.D. and a.d. are related to other measures of uncertainty if the individual values are distributed according to a particular rule, such as the normal error function in the **Gaussian error function**.

AVERAGE VALUE. In electricity, the value of a sinusoidal quantity, such as voltage or current obtained by multiplying the peak value by 0.636. It is not the same as RMS (or effective) value (which is 0.707 times the peak value).

AVIATION MEDICINE. That branch of medicine dealing with the effects of flight upon the human body, or with the demands of the human body under the various environmental conditions of flight. Aviation medicine is concerned with the effects of acceleration, flight at high altitudes, psychological effects brought about by flying, design of aircraft and equipment to suit the body's needs, etc.

AVIONICS. The science and technology of the application of electronics to aviation and astronautics. (See also **Astrionics**.)

AVOIRDUPOIS SYSTEM. Units and dimensions.

AWA. An English (Armstrong-Whitworth) missile of undisclosed details.

AWS. Air Weather Service.

AWSG. An English (Armstrong-Whitworth and Sperry Gyroscope) missile of undisclosed characteristics.

AXIAL COMPRESSOR. A compressor employing many stages, each consisting of a rotor and a stator. The rotor adds kinetic energy to the air stream in an axial direction, and the stator converts this kinetic energy into pressure. The outlet velocity of the air is usually equal to that at the inlet. These multi-stage axial compressors consist of one or more rows of airfoil-shaped blades mounted

on a rotor alternating with fixed rows of blades (called lattices) mounted on the casing. The stationary rows of blades serve to convert additional kinetic energy into pressure and also to direct the air into the next rotating row at the proper angle. Centrifugal force, which in the **centrifugal compressor** accounts for about half the total pressure rise, plays a secondary part in the axial compressor.

AXIS. A line so situated that various parts of an object are symmetrically located in relation to it. Also the line passing through the origin of a coordinate system which corresponds to all points of a given variable when other variables are zero. Thus, in two dimensions, the X-axis is the locus of all points whose Y-coordinate is zero. By convention missiles and aircraft have three axes called the *longitudinal*, *normal*, and *lateral*. The longitudinal axis is taken in the plane of symmetry, and the other two are mutually perpendicular; all intersect at the center of gravity of the configuration. The normal axis lies in the plane of symmetry with the longitudinal, and is also known as the *yaw axis*. The lateral axis lies in what might be thought of as the "plane of the wings," and is also known as the *pitch axis*. Axes for missile attitude reference are sometimes described within the missile as the pitch, roll and yaw axes. This refers to the axes about which such motions may be detected. Accelerometers and rate gyros measure components about these three axes.

Axes for position reference are traditionally referred to the earth. These begin from the horizontal (actually the vertical is the basic reference since gravitational leveling devices are used to determine the horizon), and by some convention assume two other mutually perpendicular directions, one of which may be toward the north pole. In denoting missile flight paths (for data reduction purposes) the direction from the launch point to the impact point is defined as the "X" axis positive downrange; "Y" is the off-range direction positive to the right when looking downrange, and "Z" is the altitude (measured with respect to the launch point origin, of course). This convention is normally used with aerodynamically supported missiles where flight path over the earth is most important. For ballistic missiles where lateral deviations are minor, the main interest is in range and altitude,

and ordnance convention has defined the coordinate system as a rectangular Cartesian system with the "X" axis fixed by some downrange direction (either to the impact point or to the aiming point, which is necessarily different from the impact direction to correct for the **Coriolis effect**, and the "Y" axis defined as the local vertical. "Z" is then the off-range direction, positive to the right when looking downrange, which is mutually perpendicular to the first two coordinate directions.

For solution of internal guidance equations, ballistic missiles often use reference axes taken from the impact point, with the first axis (Y) being defined as the tangent to the trajectory at that point, and the second axis (X) being chosen in the plane of fire, perpendicular to the trajectory tangent. The third axis (Z) is chosen laterally perpendicular to the plane of fire axis. This convention assists in eliminating one position error as the missile comes in to impact, for as long as the other two coordinates are correct, an error in the tangent axis cannot displace the missile from the impact point, but can only cause it to be advanced or retarded in time.

AXIS, ELASTIC. The locus of all points through which a force may be applied to a structure without causing torsional deflection.

AXIS OF AN AIR VEHICLE. One of three fixed lines of reference, usually centroidal and mutually perpendicular. The horizontal axis in the plane of symmetry is called the longitudinal axis; the axis perpendicular to this in the plane of symmetry is called the normal axis; and the third axis perpendicular to the other two is called the lateral axis. (See also **Axis**.)

AXIS, WING. The locus of the aerodynamic centers of all the wing sections.

AXISYMMETRICAL. Symmetrical about an axis. For wind tunnel models, the term denotes a circular cross section.

AZEL-SCOPE. A radar oscilloscope showing both azimuth and elevation.

AZIMUTH. A direction expressed as a horizontal angle usually in degrees or mils and measured clockwise from north. Azimuth may be **true azimuth**, **magnetic azimuth** or

grid azimuth depending upon which north is used.

Astronomical azimuth may be computed by solving the **astronomical triangle**, provided three other parts are known. In most cases the **latitude** of the observer, the **hour angle**, and **declination** of the object are the known parts. In case the **longitude** of the observer is not accurately known, the **altitude** of the object may be obtained and combined with latitude and declination for computing azimuth.

AZIMUTH ANGLE. For plane-polarized light incident on the surface of a dielectric, the angle between the plane of vibration and the normal to the plane of incidence. This same word applies to incident, reflected and refracted light.

AZIMUTHAL EQUIDISTANT CHART. A modification of the **polar gnomonic chart** in which the parallels of latitude increase uniformly in radius so that the latitude scale is constant.

AZON. The popular name of a rudimentary gravity-powered radio command guided air-to-surface missile used during World War II. It was technically the VB-1. It consisted of a general purpose 1000 pound M-65 bomb with a special tail control surface attachment permitting in-flight azimuth control. The Azon was used in 1944 against the locks of the Danube River, the Aviso Viaduct below the Brenner Pass, and in the Burma Theater, especially against railroad bridges. It had a square shaped tail assembly in which the con-

trol equipment was carried. Gyroscopes were used for attitude reference while control was by radio command—line of sight. Visual tracking was necessary and a flare was carried in the tail. The Azon could be guided only in azimuth (hence name Az only); later developments produced the Razon, a similar missile able to maneuver in pitch also. It cost three times as much as a 1000 pound bomb but was estimated to be thirty times as effective. (See also **Razon**.) The first models appeared in 1943 and were tested at Eglin Field, Florida. More than 15,000 had been produced by V-E day. The project was canceled during the war in favor of weapons with built-in automatic homing systems. During tests, however, the weapon proved to be extremely accurate and the program was re-instated. The first tactical use was in 1944 in Italy when B-17 crews of the 15th Air Force, previously trained with the Azon, dropped some in the Brenner Pass.

AZUSA. A guidance or range instrumentation system using directive antennas and phase comparison (coherent carrier) techniques for angle determination and multichannel sub-carriers for range (distance) measurements by means of time delay. Equipment includes an elaborate ground antenna array, a transmitting and receiving station and a missile borne transponder. The system was developed by Convair. Azusa is used for ballistic missiles and is effective to slightly above the line of sight horizon. It is dependent upon the missile transponder for data and cannot be used independently.

B

B. (1) Breadth or width (*b*). (2) Element boron (**B**). (3) "Boils at" (*b*). (4) Second van der Waals constant (*b*). (5) Effective film thickness (*B*). (6) Brightness or luminance (*B*). (7) Burning perimeter of cross-section of solid propellant grain (*b*). (8) Effective span in aerodynamics (*b*). (9) Moment of inertia about lateral axis (*B*). (10) Susceptance (*B* or *b*). (11) Magnetic flux density (**B**).

B BATTERY. The power source for the anode (plate) circuit of an electronic device which is battery-operated.

Ba. Barium.

BABBLE. The resultant interference, or cross-talk, from a large number of interfering channels.

BABS. Blind approach beacon system. A pulse-type ground-based navigation beacon used for runway approach to airfields.

BACK ELECTROMOTIVE FORCE. Electromotive force, back.

BACKFIT. Retrofit.

BACKGROUND. (1) A general term for the totality of the effects that are always present in physical apparatus, and above which a phenomenon must show itself in order to be measured. Such unrelated effects include the unwanted counts or currents from cosmic rays in electrical apparatus for measurement of radioactivity, developable grains on photographic plates that are unrelated to the phenomena investigated, noise in acoustical apparatus, and many others. (2) An object or objects, especially on the earth's surface, that produce signals on a radar screen but are of no particular interest; "background" returns.

BACKHEATING. In magnetrons, the increase in cathode temperature due to high-velocity electrons being returned to its sur-

face. It may be sufficiently severe to cause burnout.

BACKLASH. In a mechanism or control system, the dead space or unwanted movement due to imperfect fabrication.

BACK-SCATTERING. The deflection of particles or of radiation by scattering processes through angles greater than 90° with respect to the original direction of motion.

BACKSCRATCHER. An umbilical connection to a missile, usually of the flush-mounted type.

BACK-TO-CHEST ACCELERATION. Accelerating force acting on the human body in the direction from the back to the chest, as occurs when seated in an aircraft moving with increasing speed. It is a type of transverse acceleration.

BACKWARD WAVE. Wave, backward.

BACKWARD WAVE OSCILLATOR. Oscillator, backward wave.

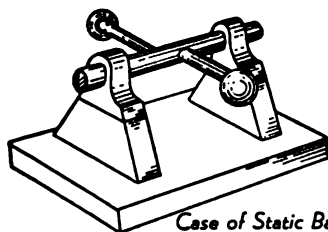
BAFFLE. (1) A shielding or deflecting structure or partition. (2) In acoustics, baffles are partitions used to increase the effective length of the external transmission path between two points in an acoustic system, usually to prevent interference or reduce sound intensities. (3) In fluid dynamics, baffles are partitions used to modify fluid flow patterns, sometimes in the form of thin metal discs with openings to reduce fluid pressure. (4) In waveguides, baffles are plates used to change wave phase or direction, or to reduce signal amplitude.

BAKA. A Japanese air-to-surface piloted missile introduced in the Pacific Theater during World War II (1944). It was an air-launched vehicle weighing approximately 4500 pounds of which 1135 pounds were warhead. The operating range of this weapon was approximately 55 miles. The missile was

launched from a mother aircraft at approximately 27,000 feet altitude. Power was from three solid propellant rockets of 1760 pounds thrust each over a burning time of 8 seconds. Guidance was by pilot who flew to his destruction with the missile. Targets were naval vessels. Lack of maneuverability proved a serious defect.

BALANCE, DYNAMIC. Balance, mechanical.

BALANCE, MECHANICAL. Mechanical balance consists of the equilibrium of masses, and can be divided into static and dynamic balance. Static balance occurs in a system when the **center of gravity** of the system coincides with its reactions. For example, a rotating body in static balance has its center of gravity coincident with its axis of rotation. A system may, however, be in static balance, but become unbalanced when the system rotates. Such a system, for example, as that shown in the accompanying figure may well be in static balance, and satisfactorily pass a



*Case of Static Balance
and Dynamic Unbalance*

balance test which would consist of putting the shaft on absolutely horizontal parallel rails and trying the rotor for equilibrium in any position. But when this system rotates, the centrifugal forces of the two weights, not being in the same plane perpendicular to the axis of rotation, create a couple acting on the shaft. That couple rotates with the shaft and produces shaking forces at the journals, and vibrations in the foundation. The dynamic balancing of this system would involve the addition of a system of counter balances which, by themselves, would be in static equilibrium, but which in rotation would produce a couple equal in magnitude but opposite in direction to the one already considered.

BALANCE-UNBALANCE. Balun.

BALANCED LINE SYSTEM. A system consisting of generator, **balanced line**, and load,

adjusted so that the voltages of the two conductors at all transverse planes are equal in magnitude and opposite in polarity with respect to ground.

BALANCED LINE (TWO-CONDUCTOR).

A **transmission line** consisting of two conductors in the presence of ground, capable of being operated in such a way that when the voltages of the two conductors at all transverse planes are equal in magnitude and opposite in polarity with respect to ground, the currents in the two conductors are equal in magnitude and opposite in direction. A balanced line may be operated under unbalanced conditions, and the aggregate then does not form a balanced line system.

BALANCED SURFACE, AERODYNAMIC.

A control surface that extends on both sides of the axis of the hinge or pivot, or that has auxiliary devices or extensions connected with it in such a manner as to effect a small or zero resultant moment of the air forces about the hinge axis.

BALANCED SURFACE, STATIC. A control surface whose center of mass is in the hinge axis.

BALANCER. (1) The circuit employed to balance out the **antenna effect** due to antenna-to-ground capacitance in **radio direction-finders**. (2) A machine consisting of two rotating devices, mechanically coupled, used to maintain or approximate balanced voltages on a three wire d-c line. When the load between one of the outer wires and ground is increased so as to decrease the voltage across this "leg," the half of the balancer connected across the leg acts as a generator, driven by the half of the machine across the other leg.

BALLADROMIC COURSE. A missile heading which will result in a hit on the target.

BALLAST. A substance included in the payload of a missile for the purpose of changing weight or load characteristics in order to preserve desirable aerodynamic characteristics. During the Research and Development phase, warheads are seldom used; the space where they normally go is usually filled with telemetry and other special research and development equipment. The remainder of the warhead weight might be made up with ballast.

BALLAST RESISTOR. A resistor having a resistance that increases with increasing current, and thus tends to equalize the effect of voltage fluctuations across the circuit with which it is in series.

BALLAST TUBE. A vacuum tube containing a ballast resistor.

BALLISTIC. Of or pertaining to ballistics.

BALLISTIC ASCENT. The ascent of a space vehicle from earth to its orbit, when that ascent follows the trajectory marked "Ballistic Ascent" in the illustration found under **elliptic ascent**. Ballistic ascent is considered to take place in two propulsion periods, as shown. As will be seen by comparing the paths of elliptic ascent and ballistic ascent, the latter requires much more power. However, it has its advantages under certain conditions, as for instance, for tracking purposes, where visibility from the launching site or from a near-by apogee is required.

BALLISTIC CAMERA. A camera used to photograph high velocity flight phenomena. It is usually fixed in position with continuously open shutters or with very high frame speed so that successive images at precise times are available for study. Ballistic cameras must be used in pairs or larger groupings for space positions to be obtained. The accuracy of such cameras can range from one part in 50,000 downward, depending upon the quality of camera, mount, lens system, plate and emulsion precision, and the systematic corrections applied. It is customary to correct ballistic camera data for such minor errors as refraction, deviation of the local vertical and other minor effects if very accurate results are to be obtained. *Ballistic* cameras are especially good where tracking cameras fail because of high transverse rates or other shortcomings. Ballistic cameras are usually used to cover the terminal or launch-phases of flight. One of the common ballistic cameras is the *Bowen-Knapp*. This camera may be adjusted in azimuth, elevation and tilt. It is then fixed in this orientation to cover a fixed portion of the flight path. The *Wild BC-4* ballistic camera is the most refined instrument available for range use. Its plate resolution is accurate to one micron, with especially ground glass plates and special photographic emulsions. These cameras are used

mostly at night when they can be calibrated by star sightings. They then photograph a flashing light source on the missile or photograph the missile's exhaust (chopping it in synchronism with another camera for tie-in).

BALLISTIC COEFFICIENT. A coefficient expressing the relative efficiency of a missile in overcoming air resistance.

BALLISTIC CONDITION. Any one of the conditions affecting the motion and behavior of a missile in flight.

BALLISTIC CONE. A model of a recoverable reentry satellite recently released by the National Advisory Committee for Aeronautics. It carries a payload capsule within a heat-absorbing shield, but separated from it by an air gap and surface insulation. It could have retro-rockets and a parachute for reentry, since its payload would consist chiefly of instruments. (See illustration facing Page 507.)

BALLISTIC CURVE. The curve described by the actual path of a missile, or other projectile, as determined by the ballistic conditions, which include the forces exerted by the propulsion system, gravitational fields, winds, etc.

BALLISTIC DEFLECTION. The deflection of a missile due to its ballistic characteristics.

BALLISTIC EFFICIENCY. (1) The efficiency of a missile in overcoming air resistance, gravity, and other ballistic conditions. (2) The external efficiency of a rocket or jet engine of a missile.

BALLISTIC FACTOR. A parameter used to describe flight performance of bodies in free fall. It is abbreviated C_B .

BALLISTIC GALVANOMETER. Galvanometer.

BALLISTIC GUIDED MISSILE. A missile whose guidance is accomplished primarily by means other than aerodynamics, e.g., the German "V-2."

BALLISTIC MEASUREMENT. Any measurement in which an impulse is applied to the measuring device and the subsequent motion of the device is determined as a measure of the impulse. (See **Ballistic Pendulum**.)

BALLISTIC MISSILE. A missile designed primarily in accordance with the laws of ballistics; specifically, a self-propelled guided missile for surface targets that depends primarily upon the thrust of its propelling system and upon momentum, rather than aerodynamic lift, for its support during flight, and that depends primarily upon jet reaction, rather than aerodynamic reaction, for its control.

A ballistic missile is guided during a portion of its flight, usually the upward portion, and is under no thrust from its propelling system during the latter portion of its flight; it describes a trajectory throughout similar to that of an artillery shell.

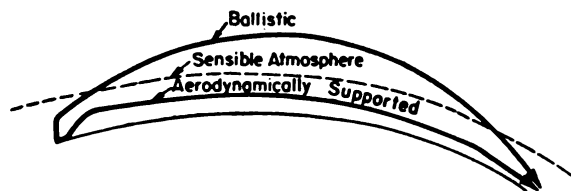
BALLISTIC MISSILES OFFICE. (BMO) An office of Headquarters U.S. Air Materiel Command established at Inglewood, California, to provide a streamlined logistics system for IRBM's and ICBM's.

BALLISTIC PENDULUM. An instrument used for measuring the horizontal velocity component of a projectile. In its usual form it consists of a simple pendulum of mass M , and of natural frequency f . A projectile of mass m , moving with a velocity V strikes the bob and is imbedded in it. The maximum excursion X of the bob is then measured. Assuming that $M \gg m$ and that little damping is present, it may be shown by application of conservation laws that

$$V = \frac{2\pi f X M}{m}$$

BALLISTIC TEMPERATURE. A theoretical constant temperature that would have the same effect on a missile in flight as the varying temperatures actually encountered.

BALLISTIC TRAJECTORY. The path traveled by an initially moving object in free fall through space or the atmosphere. In the case of a missile or other propelled vehicle, the ballistic trajectory is the path traveled after the propulsive force has ceased to act, when



Basic trajectories.

gravity and possible atmospheric friction are the only forces effective. When the reaction of the air is sufficient to modify the course of the missile significantly, it is said to have an "aerodynamic trajectory." (See figure.)

BALLISTIC WAVE. An audible disturbance caused by the compression of air ahead of a missile in flight.

BALLISTIC WIND. That constant wind which has the same first order effect as the actual wind.

BALLISTICS. The science or art that deals with the motion, behavior appearance, or modification of missiles acted upon by propellants, rifling, wind, gravity, temperature, or any other modifying substance, condition, or force; the art of designing missiles so as to give them efficient motion and flight behavior within the limitations set up by their purpose. Conventional division of the subject of ballistics is into three parts: *interior ballistics*, which deals with the motion of missiles in confined spaces, as in the tube of a gun; *exterior ballistics*, which deals with the motion of missiles through air or space; and *penetration ballistics*, which deals with the penetration of bullets or shells into solid material. This term penetration ballistics is sometimes applied to the behavior of missiles upon re-entering the atmosphere from space, although for this use the expression *terminal ballistics* is to be preferred.

BALLISTITE. One of the first smokeless powders, invented by Alfred Nobel. It consists of about 60% nitrocellulose and 40% nitroglycerine, and is thus a double-base propellant. Double-base powders contain small quantities of additives (e.g., stabilizers or plasticizers). Ballistite propellants have a specific impulse of around 230 lb-sec/lb and their exhaust is smokeless. The main objection to them is that they are sensitive to temperature changes, the chamber pressure increasing with ambient temperature at the rate of approximately 1% per degree Fahrenheit. Ballistite also tends to decompose under high temperature storage conditions, e.g., storage for more than two weeks at 140°F is considered undesirable. Ballistite can be prepared from nitrocellulose, nitroglycerine and the other ingredients by either a solvent or a solventless process. The solvent process is

used for small (less than 0.25 inch) **web thickness** and the solventless ballistites are used for thicker webs.

BALLONET. A sealed compartment of a variable volume placed in a fluid system for the purpose of compensating for changes in volume of fluid within the system. In lighter-than-air craft, such a compartment, constructed of fabric, is placed within the gas container of the ship. It is partially inflated with air as necessary to compensate for changes of volume of the gas contained in the envelope, and so keeps the envelope taut.

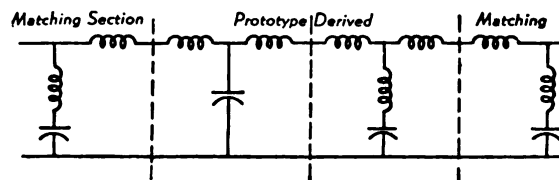
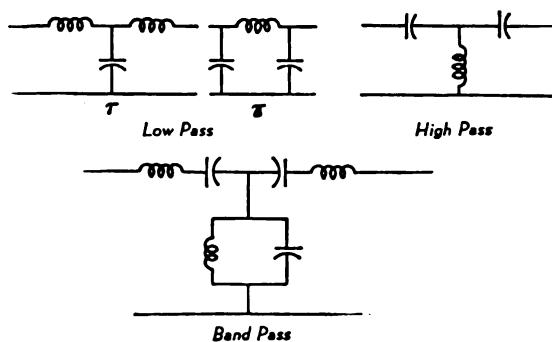
BALLOON TANKS. Propellant or fuel tanks which depend on internal pressure to stabilize the tank walls for compressive load carrying capability.

BALUN. A term derived from the words (balanced to unbalanced) which is applied in general to devices used for the transformation from an unbalanced (coaxial) **transmission line** transformer, or system to a balanced (two-wire) line or system, in which the two terminals have equal impedances to ground. Some change in impedance level may also be introduced between the balanced and unbalanced terminal-pairs of the device.

BAND (OR ENERGY BAND). Frequency band; spectrum, band: band theory of solids.

BAND-ELIMINATION FILTER. Two or more tuned circuits adjusted to attenuate highly a band of frequencies within predetermined upper and lower frequency limits. The graphical result (selectivity curve) is ideally an approximation to a square wave which has the required width.

BAND-PASS FILTER. A wave filter whose transducer gain is near unity for a certain



band of frequencies, but falls to low values at frequencies above and below this band.

BAND, SIDE. A component in **carrier wave** transmission having a frequency equal to the sum or difference of the frequency of the carrier wave and that of the **modulating wave**.

BAND SPECTRUM. Spectrum, band.

BANDSPREAD METHOD. A means of close control of the tuning range of a given frequency band. It is generally accomplished by a low capacity variable condenser in parallel with the main tuning condenser. It "spreads" the band by making it necessary to turn its dial farther to change the capacitance effectively. It thus moves farther apart the dial settings for two incoming signals.

BANDWIDTH. The difference in frequencies between the lowest and highest effective frequencies. Typical applications of the term are to a tuned circuit, to a modulated radio signal servomechanism, or to radio station channel assignment.

BANDWIDTH, DESIGN. The frequency deviation any device is intended to achieve with full range stimulus.

BANDWIDTH, EFFECTIVE. (1) For a specified **transmission system**, the bandwidth of an ideal system which (a) has uniform transmission in its **pass band** equal to the maximum transmission of the specified system, and (b) transmits the same power as the specified system when the two systems are receiving equal input signals having a uniform distribution of energy at all frequencies. This may be expressed mathematically as follows:

$$\text{Effective band width} = \int_0^{\infty} Gdf$$

where f is the frequency in cycles per second and G is the ratio of the power transmission at the frequency f , to the transmission at the frequency of maximum transmission.

(2) For a band-pass filter (see **filter**, **band-pass**) the width of an assumed rectangular band-pass filter having the same **transfer ratio** at a reference frequency, and passing the same mean-square value of a hypothetical current and voltage, having even distribution of energy over all frequencies.

BANDWIDTH OF A DEVICE. The range of frequencies within which performance, with respect to some characteristic, falls within specific limits.

BANG-BANG. A discontinuous servo type of missile control in which correcting maneuvering signals are sent to the control surfaces commanding a "full-over" response. Variations in degree of movement are obtained by varying the number of repetitions of the "bang-bang" command. The surface is capable of only one control response—it "bangs" over to its stop and when the command is removed it "bangs" back to neutral. The "bang-bang" cycle may be slow enough to permit it to be cut off before a complete response is obtained, but if the command were continued the control surface would eventually hit the control stop. The radio-controlled airplane targets (OQ planes) use this type of command control. It is also called "flip-flop" control, "flicker" control or "black-white" control.

BANK-AND-TURN INDICATOR. A flight instrument containing in a single housing a **bank indicator** and a **turn indicator**, the instruments being used in conjunction.

BANK INDICATOR. A flight instrument which shows, with respect to the horizon, an air vehicle's angle of roll about its longitudinal axis.

BAR. (1) Bureau of Aeronautics Representative. (2) A unit of pressure equal to 1,000,000 dynes per square centimeter. A bar equals 100 centibars, 1000 millibars, or 1,000,000 microbars.

BARIUM. Metallic element. Symbol Ba. Atomic number 56.

BARN. A unit of nuclear cross section of 10^{-24} square centimeter per nucleus.

BARO FUZE (BAROMETRIC FUZE). A device similar to an aneroid-type altimeter

used to perform certain program steps in the arming and detonation of an explosive device.

BAROGRAPH. A recording **barometer**.

BAROMETER. An instrument for measuring the pressure of the atmosphere.

BAROMETER, ANEROID. A **barometer** in which an evacuated metal bellows equipped with a sensitive diaphragm is the actuating element. Changes in atmospheric pressure cause it to contract or expand and to move an indicating device over a calibrated dial.

BAROMETER, MERCURY. A column of mercury in an upright tube at least 80 cm long, from which the air has been exhausted; the upper end is sealed, and the lower dips into a cup containing mercury, which is open to the air. The height of the mercury column in the tube indicates the atmospheric pressure.

BAROPORT. An opening on an aerodynamic surface where the effects of velocity on local air pressure introduce the least uncertainty in predicted altitude versus pressure relationships.

BAROSWITCH. A pressure-sensitive device which provides a signal to a circuit, e.g., a switch to arm or actuate a nuclear warhead upon reaching a given altitude.

BASE. (1) A supply or operational center. (2) A foundation or support. (3) One of the connections to a **transistor**, playing the role of the **cathode** in a vacuum tube. (4) Any substance which can replace the hydrogen of an acid, or which contains hydroxyl groups capable of uniting with the hydrogen of an acid to form water and a salt, or which contains trivalent nitrogen and can add directly to an acid to produce a salt in which the nitrogen is pentavalent.

BASE COMPLEX. An air base for support of Air Force units consisting of landing strips and all components or related facilities for which the Air Force has operating responsibility, together with interior lines of communication and the minimum surrounding area required for local security. (See **Launch Base Area**.)

BASE DRAG. Drag.

BASE HARDNESS. The degree to which a missile facility installation is protected against

enemy inflicted damage, especially from nuclear detonations. (See **Soft Structure, Hard Structure.**)

BASE LINE. (1) An accurately measured distance from the end points of which surveys or other angular measurements are made. The probable errors of survey base lines are: first order— $1/1,000,000$; second order— $1/500,000$; third order— $1/250,000$. (2) A glowing line on a radar screen, representing the track covered by a radar scanner. Echoes from reflecting objects appear as pronounced irregularities in the line. (3) A line between two radio transmitters, usually a line joining a master **loran** station with a slave station.

BASE PLATE. A sheet of iron or other metal placed under a **missile** launching platform to give flotation to the **launcher**.

BASE PRESSURE. The pressure at the rear or base of a **missile**. The base pressure has a large negative value with reference to the free stream pressure, thereby creating considerable drag, especially if the base is large. (The presence of a jet at the rear of a missile will decrease the effective base area as long as the jet is in operation.)

BASE SUPPORT EQUIPMENT (BSE). That portion of the unit mission equipment for tactical operation units which permits the establishment of base-type functions necessary to support a tactical mission.

BASE SURGE. The concentrated wave or cloud of mist or dust which shoots out from the foundation of the column by an underwater or underground nuclear explosion.

BASIC FREQUENCY. **Frequency, basic.**

BASIC LOAD. **Load, basic.**

BAT. (1) A U.S. Navy research project during World War II for investigating the possibility of using bats to carry incendiary materials against the enemy. A time-fuzed incendiary was to be attached to bats which would be released over enemy targets. The bats were expected to take refuge in buildings during the daylight hours, where the time device on the incendiary would explode. (2) A U.S. Navy winged and tailed glide-bomb approximately 12 feet long, with a 10-foot wing span and a 20-mile range. It was used

against Japanese shipping during World War II. The Bat was carried under the wings of the Privateer patrol bombers, launched outside the enemy's defense perimeter. The Bat contained a 1000 pound bomb, and a radar for homing on discrete targets. It is believed to be the first successful radar homing system used in guided missiles. (See illustration facing Page 59.)

BATTERY. (1) Any group of duplicate units which contribute individually to a common effect. An example is the artillery battery (or missile battery), consisting of a tactical group of guns (or missiles) usually numbering two to six or more. (2) By far the most common usage of the word is in reference to a collection of electrochemical cells for the production or storage of electrical energy. (See **battery, primary; battery, secondary.**) These electrochemical batteries consist of electrodes immersed in solutions called electrolytes which react with them chemically to produce electrical energy which flows through an external circuit connected to the electrodes. Such batteries have the following advantages for missile power: (a) reliability; (b) maximum energy output per unit weight (approximately 50 watt hours/pound) and per unit volume; (c) good voltage regulation; (d) temperature stability; (e) long shelf life; (f) resistance to missile environments such as vibration, shock, etc.

Among the types of batteries used in missiles and rockets are the following: (a) the common storage battery in which the electrodes are lead and lead oxide and the electrolyte is dilute sulphuric acid; (b) the battery using plates of silver oxide and zinc and an electrolyte composed of potassium hydroxide solution; (c) the battery having plates of nickel oxide and cadmium in an electrolyte of potassium hydroxide solution. In addition to these electrochemical batteries there are also the **solar batteries**, which derive their energy from the photovoltaic action of sunlight, and the **radioactive batteries** which are energized by electrons emitted from radioactive elements such as strontium-90 and krypton-85.

BATTERY, B. A **battery** used to apply potential between the cathode and anode (plate) of electron tubes.

BATTERY INVERTER ACCESSORY POWER SUPPLY (BI-APS). An interim battery-

motor-alternator combination that supplies electrical power for missile operation.

BATTERY, PRIMARY. A group of cells for the transformation of chemical into electrical energy. While the chemical reactions are reversible, the primary battery is not designed to operate reversibly, and is so distinguished from the secondary battery (see **battery, secondary**).

BATTERY, RESERVE. An electrochemical **battery** which is characterized by long shelf life in an unenergized state. Electrolyte is added when available electric power is desired.

BATTERY, SECONDARY. A group of cells for the transformation of chemical into electrical energy and the reverse. As usually arranged, the substances produced by the reaction that yields the electrical energy are restored to their original chemical form by the passage of d-c current in the reverse direction to that of discharge.

BATTERY, THERMAL. (1) An electrochemical **battery** that is activated by applying heat to melt a solidified electrolyte. (2) A source of electrical energy consisting of a junction of two metals which produce an emf when heated.

BATTLESHIP DESIGN. A heavy structure simulating an airborne vehicle and having certain, usually very rugged, characteristics to permit its use for special tests.

BAUD. The unit of telegraph signal speed. A telegraphic speed of one baud is one pulse per second.

BAUMÉ SCALE. A hydrometer scale which is used for measuring the **specific gravity** of liquids, their relative weight as compared to the weight of an equal volume of a standard liquid. There are two Baumé scales: one for liquids which are heavier than water; the other for liquids which are lighter than water. For liquids heavier than water, the conversion formula is:

Degrees Baumé (American)

$$= 145 - \frac{145}{\text{specific gravity } 60/60^{\circ}\text{F}}$$

For liquids lighter than water, the conversion formula is:

Degrees Baumé

$$= \frac{140}{\text{specific gravity } 60/60^{\circ}\text{F}} - 130.$$

BAY. (1) One segment of an **antenna array**.
(2) A housing for transmitter equipment.

BAYONET-TYPE SOCKET. A type of mechanical quick-disconnect socket consisting of a right-angled slotted arrangement in the socket recess into which a lug on a plug fits when the plug is properly seated. A spring in the base of the connection pushes outward on the plug to give good contact.

BAZOOKA. The U.S. rocket launcher first used during World War II. The original Bazooka was 2.36 inches in diameter. The 3-5-inch "Super-Bazooka" was used first in Korea. (See also **Rocket, 2.36 inch** and **Rocket 3.5 inch**.)

BDA. Bomb Damage Assessment.

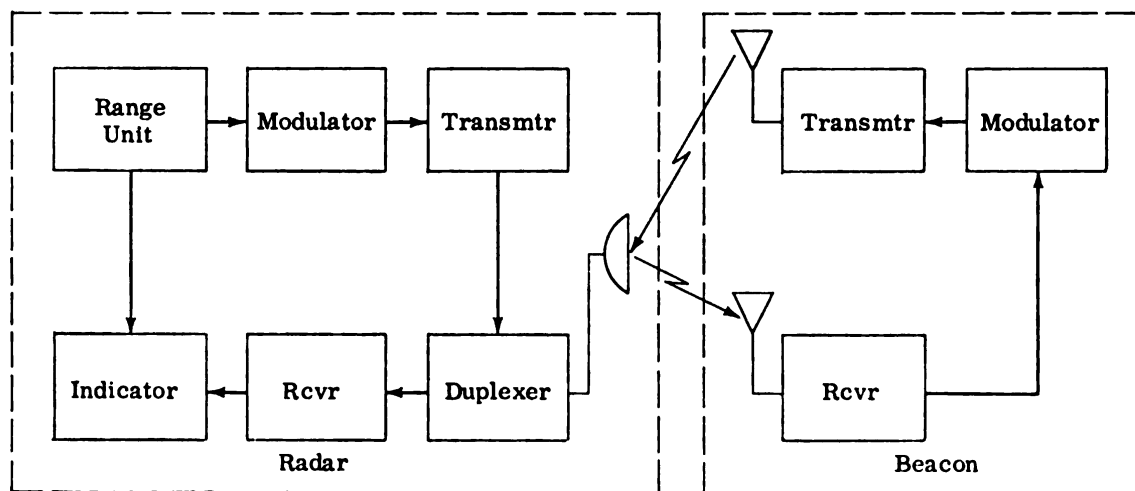
BDS. Bomb Damage Survey.

Be. Beryllium.

BEACON. A signal emitter for use as a guidance, tracking or warning aid.

BEACON, DELAY. In any radar beacon (see **beacon, radar**) arrangement, the interrogation, triggering, and response of the beacon takes a finite time determined by the time constants of the circuits involved, and usually constant for a particular beacon. It may be designed for a wide range of values extending from a few microseconds to any value necessary to meet operational requirements; the name "delay beacon" is applied to the latter.

BEACON, RADAR. A vehicle-mounted transmitter which transmits a high frequency signal to a receiver, usually on the ground, designed to track the vehicle. In missile applications, the radar beacon is mounted within the missile and is triggered to transmit when the ground radar signal reaches it. The missile radar beacon returns to the ground radar a response which is sometimes at the same frequency as the signal received. Thus it serves to reinforce the radar signal from the ground, as contrasted with the systems which depend merely upon reflection of that signal by the vehicle. (See figure.) Usually, how-



Radar beacon system.

ever, the beacon is operated at a slightly different frequency to identify the missile.

BEAM. (1) A directional electromagnetic radiation, as a radar beam. (2) A flow of electromagnetic radiation or of particles that is essentially unidirectional. (3) A straight or initially curved member which supports bearing loads without the aid of arch action (see specific types of beams which follow). (4) The term **beam** is also used to designate certain rolled-steel sections, such as the I-beam, which may be used either as beams, as defined in (3) above, or as **columns**.

BEAM CAPTURE. In a radar beam riding guidance system, the act of placing the missile in the radar beam so as to provide coded guidance signals.

BEAM DIRECTION. (1) The axial direction of a narrow or well defined electromagnetic radiation. (2) The direction parallel

to the plane of the spar web and the plane of symmetry of an airplane.

BEAM JITTER. In a beam-rider guidance system, a small oscillatory, angular movement induced into the radar antenna array, and consequently into the radar beam. This movement is caused by: (a) the necessity of having to develop an error signal, when in automatic tracking, before the antenna will change its position, or (b) the circuitry intentionally made "tight" to obtain plus and minus tracking errors rather than only lagging errors, or (c) gear play in the radar tracking head.

BEAM-RIDER GUIDANCE. A system for guiding missiles in which a missile follows a radar beam, light beam, or other kind of beam directed along the path it is desired for the missile to follow. The beam used may be either fixed or movable, and the missile is provided with devices to detect its deviation

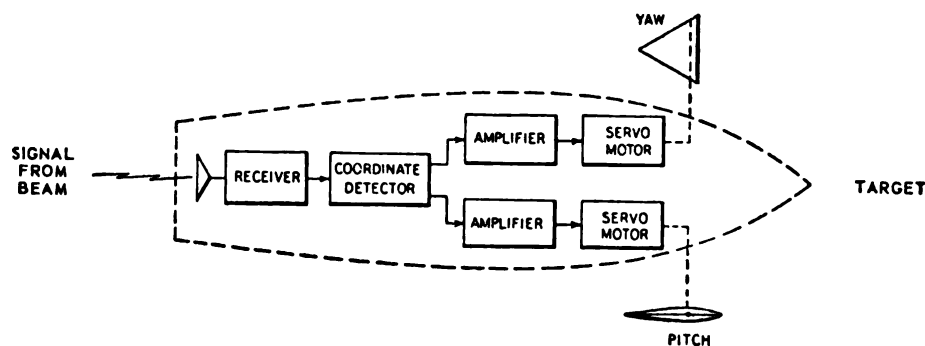


Fig. 1. Beam rider guided missile.

from the beam and to return it to the beam automatically. Also called "beam-climber" guidance.

BEAM-RIDING MISSILE. A guided missile that is directed to its target by beam-rider guidance.

BEAM-RIDING SYSTEM (BEAM RIDER).

A guidance system in which the missile is directed along a line (often the line-of-sight) between the beam source and the target no matter whether corrective control commands are generated automatically within the missile (true beam-rider) or at a control point on the ground and transmitted to the missile (command system). (See Figs. 1 and 2.)

target evasions is much greater. (See also **Guidance; Guidance, Beam Rider.**)

BEAM WIDTH. The angular separation in azimuth between the two directions to the right and left of the center of a radar beam, at which the gain is one-half that at the center. Beam width may be measured also in elevation, in the vertical plane, or in an inclined plane. (See **Side Lobe; Half Power.**) (See figure on Page 84.)

BEARING. In navigation, both air and sea, the term bearing is used to indicate direction. It is the angle, measured at the observer, or some specified point, between two lines in the plane of the horizon. Careful distinction

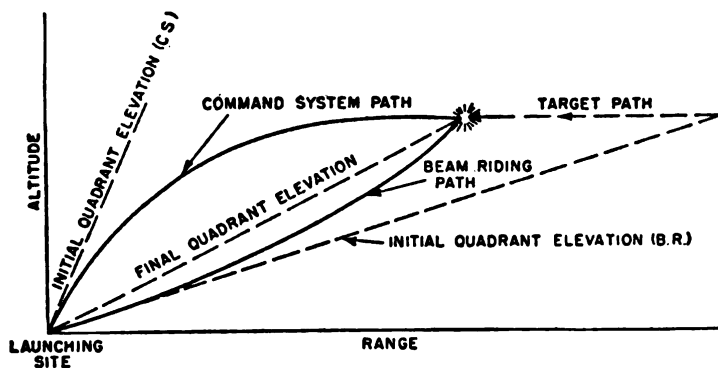


Fig. 2. Command and beam rider flight paths.

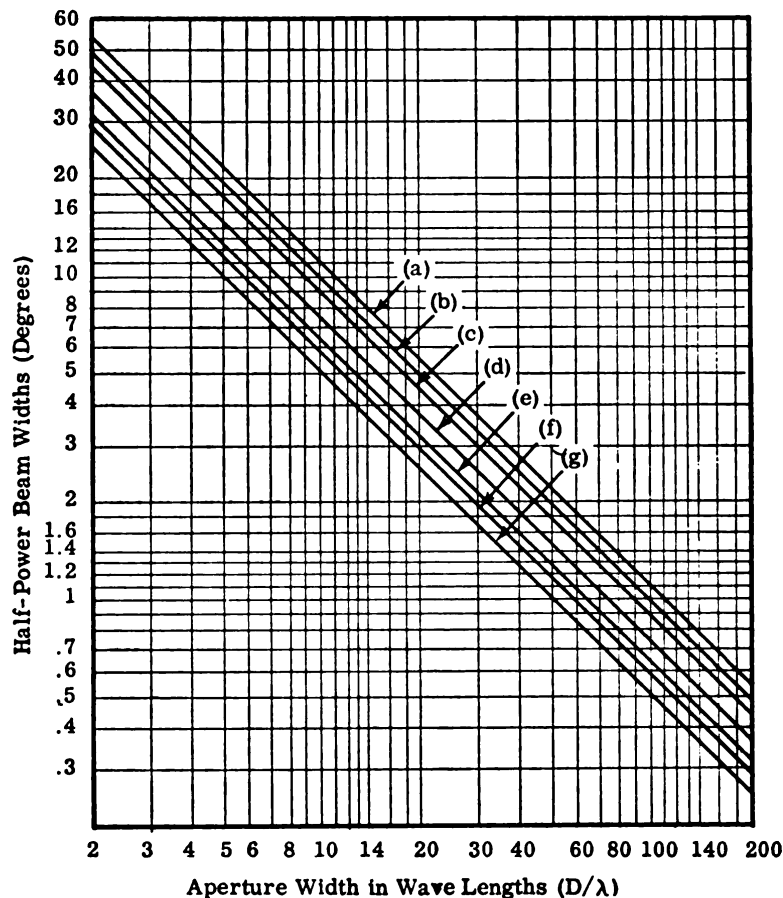
The first system consists essentially of a beam of electromagnetic energy (usually in the radar frequency range) which is directed toward the target so as to follow it at all times. Equipment within the missile is designed to distinguish between small changes in intensity of the energy in the beam, and if the missile goes off the center of the beam, a correcting control mechanism brings it back. The only ground guidance equipment required with this system is the target illuminating beam, all the other guidance equipment being carried in the missile. The beam-rider missile system has both advantages and disadvantages. It permits the launching of a large number of missiles into the same control beam, since all the guidance equipment is carried on each missile. This feature, however, makes each missile costly and large. The radar problem is a simple one since only one radar set is required, but the controlling beam must be reasonably narrow to be directive, and thus the likelihood of loss of the missile due to

must be made between the meaning of the term bearing when used alone and the same term when qualified, e.g., relative bearing, compass bearing, etc.

The bearing of a given point from the observer is simply the true direction of that point, expressed in the conventional manner for expressing direction, i.e., to the right, through 360°, and in three digits.

If the compass is used for finding the bearing of a point from a ship, the value obtained will be the compass bearing and the **compass corrections** must be applied to obtain true bearing. Methods for obtaining bearings by using the **pelorous** are explained in the article on that instrument.

Frequently it is easier to use a ship's keel as a reference line, rather than north, for determining bearing. In this case relative bearing is obtained. This is defined as the angle between the keel of the ship and a line in the plane of the horizon to the object. This angle is measured from the forward end

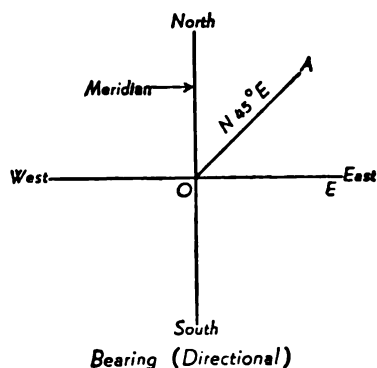


Curve	Illumination Taper	Theoretical First Side Lobe Level	Curve	Illumination Taper	Theoretical First Side Lobe Level
(a)	(Cosine) ⁴	44.6 db	(e)	Average antenna	20.0 db
(b)	(Cosine) ³	39.0 db	(f)	Uniform	17.6 db
(c)	(Cosine) ²	32.8 db	(g)	Uniform	13.2 db
(d)	(Cosine)	25.8 db			

Curves (a) thru (f) are for circular or elliptical apertures. Curve (g) is for rectangular aperture.

Antenna half-power beam width vs. aperture width.

of the keel, to the right through 360°, and expressed in three digits. To find the bearing of the object when the relative bearing is known, the **heading** must be added to the relative



bearing. For example, a ship is heading 326° and the relative bearing of a buoy is 124°. The bearing of the buoy is 326° + 124° = 450°, or 090°, and the buoy is due east of the ship. **Radio bearings**, taken with a radio direction-finder, are always given as relative bearings from the ship.

BEAST (BIRD). Slang term for a missile.

BEAT(S). A series of alternate maxima and minima in vibration amplitude, produced by the interference of two wave trains of different frequency. A familiar example arises in the case of musical sounds. If two musical pipes or strings of slightly different pitch are sounded together, the result is a more or less



Five coincidences in unit time between wave trains of frequencies 20 and 25.

distinct throbbing, often disagreeable to the ear. The beat frequency is the difference of the two wave frequencies. Thus, if the two tones are middle-c (256) and c-sharp (271.2), there will be 15.2 beats per sec. If the two tones are **ultrasonic**, but have a frequency difference within the audible range, the beats themselves may produce an audible "beat tone." A similar effect results from the simultaneous reception of two radio wave trains which are nearly, but not quite, synchronized. Thus if two stations are sending on carrier waves of 1000 and 998 kilocycles, the receiver will emit a shrill whistle of frequency 2000 cycles. This is the "heterodyne" effect, responsible for the annoying squeals and tremolos often heard in radio reception. The effect is utilized in heterodyne code receivers and in the **frequency-conversion** section of the modern radio. One type of radio "**fading**" may be regarded as a beat phenomenon of long period. In missile applications the beat principle is used in many ways to indicate path deviations, velocities, and positions simply by measurements of frequencies transmitted from a beacon in the missile to two different ground points and comparing these with one another, i.e., "beating" them together. (See also **DOVAP** and **Doppler**.)

BEAT-BEAT. A system of missile course determination based upon a phase comparison arrangement. A regular **DOVAP** transponder in the missile receives a ground signal, doubles it and retransmits it to two ground receivers located on accurately measured perpendiculars to the flight line. These two stations are on the same perpendicular, one to the left and the other to the right (e.g., 100 wavelengths) of the flight line. Each of the receiver stations compares the missile transponder's doubled signal with a doubled signal from a ground transmitter to obtain a beat frequency caused by the Doppler effect of the moving missile. Each of the stations has a beat. These two beats are then mixed to obtain a combined difference frequency. This beat-beat resultant will be proportional to the deviation of

the missile off its flight course. The beat-beat instrumentation can also be applied to the flight of the missile in the program direction (i.e., downrange direction) and thus a *lateral beat-beat* and a *program beat-beat* arrangement can be had to give a complete picture of the missile's flight. The beat-beat instrumentation is somewhat more complicated than described when it shows left or right deflections as well (or uprange or downrange in the case of the program beat-beat).

BEAT FREQUENCY. The number of **beats** per unit time. When two signals of different frequencies are applied to a non-linear circuit, they will combine, or beat together, and give, among other components, one which has a frequency equal to the difference of the two applied frequencies. This difference frequency is known as the "beat frequency."

BEAT-FREQUENCY OSCILLATOR. (1) Any conventional **oscillator** whose function is to produce the signal to mix with a signal whose frequency is to be shifted. Thus in a **continuous wave** receiver, it is the oscillator causing an audible beat, in the **superheterodyne** it is the oscillator causing the intermediate frequency beat. (See **beat frequency**.) (2) An **audio frequency** oscillator containing two **radio frequency** oscillators, and supplying their beat frequency as its output.

BEATING. A phenomenon in which two or more periodic quantities of different frequencies produce, when mixed, a resultant having pulsations of **amplitude**.

BEAUFORT SCALE. An arbitrary scale from "0" through "12" devised in 1805 by Sir Francis Beaufort (1774-1857), an English rear admiral, to denote the strength of the wind. This scale and its extension through number 17 are given on Page 86.

The State of the Sea is also given by another Beaufort Scale on that page. The State of the Sea refers to the height of swells and the condition of the surface resulting from the action of the local winds. The term *swell* refers to the wave motion that "underlies" the sea, raised and driven by the local wind. Swell usually has traveled over a considerable distance from the point where it was generated by the wind, and its height may often differ widely from those of the local wind-driven waves. For example, a

BEAUFORT WIND SCALE

BEAUFORT NUMBER	DESCRIPTION	SPEED	
		MPH	Knots
0	Calm	0	Not over 1
1	Light air	1-3	1-3
2	Light breeze	4-7	4-6
3	Gentle breeze	8-12	7-10
4	Moderate breeze	13-18	11-16
5	Fresh breeze	19-24	17-21
6	Strong breeze	25-31	22-27
7	High wind or Moderate gale	32-38	28-33
8	Gale or Fresh gale	39-46	34-40
9	Strong gale	47-54	41-47
10	Whole gale	55-63	48-55
11	Storm	64-73	56-63
12	Hurricane	74-82	64-71
13		83-92	72-80
14		93-103	81-89
15		104-114	90-99
16		115-125	100-109
17		126-136	110-118

"calm sea" may co-exist with an 8-foot swell. The smaller value will be used with two code figures applying. Wave heights are measured from crest to trough. The height of swell is recorded in feet as measured from crest to trough.

quency causes an "up" motion, another tone causes a "left" maneuver, etc. The harmony of various control signals following one behind the other, "beep," "beep," "bloop," etc., describes the maneuver. (2) A small radio transmitting beacon which emits a series of

BEAUFORT STATE OF THE SEA SCALE

BEAUFORT NUMBER	DESCRIPTION	APPARENT AVERAGE HEIGHT OF WAVES
		IN FEET
0	Calm, sea like mirror	0
1	Smooth	Less than 1
2	Slight	1-3
3	Moderate	3-5
4	Rough	5-8
5	Very rough	8-12
6	High	12-20
7	Very high	20-40
8	Mountainous	More than 40

BEAVERTAIL. A fan-shaped radar beam, wide in the horizontal plane and narrow in the vertical plane. The beavertail is swept up and down for height-finding.

BEEPER. (1) A simple, remote radio-control device used for guidance of vehicles, such as a radio controlled airplane target. The name arises from the fact that various modu-

latory audio tones are used to command certain vehicle responses. A tone of one frequency interrupted signals or "beep" tones. These beacons are used in tracking missiles in the air, identifying them, or locating impacted and recoverable parts of missiles. (See also **Pinger**.) (3) An individual who directs a pilotless aircraft or missile by remote control.

BEETHOVEN APPARATUS. A Messerschmitt Me 109 or Focke-Wulf Fw-190 fighter mounted on top of a Junkers 88. The fighter pilot controlled the flight of both the bomber and his own craft. Upon approaching a bombing target the operational concept called for the pilot to dive both aircraft toward the ground and then break contact with the Junkers at approximately 4 miles distance from the target, allowing the bomber to continue under full power into the ground.

BEL. A dimensionless unit for expressing the ratio of two values of power, the number of bels being the logarithm to the base 10 of the power ratio. With P_1 and P_2 designating two amounts of power and N the number of bels corresponding to the ratio P_1/P_2 ,

$$N = \log_{10} (P_1/P_2)$$

The bel is seldom used, the decibel being usually a more convenient unit.

BELGIUM BLOCK COURSE. An environmental test facility for evaluating the transportation environment. The course is a specially prepared road bed having varying degrees of roughness, waviness, and other controlled characteristics over which wheeled equipment is moved at varying speeds to study the effect of transportation shock and vibration.

BELL CRANK. A mechanical linkage consisting of a lever arm pivoted at the center, to each end of which are attached push-pull rod connections. When one rod is moved the effect of the bell crank is to change the direction of motion transmitted, since the other rod will move about the center pivot in the opposite direction.

BEND (E-TYPE). A bend in a waveguide mode in the plane of the electric field.

BEND (H-TYPE). A bend in a waveguide mode in the plane of the magnetic field.

BENDING MOMENT. The external bending moment at any section in a beam is equal to the algebraic sum of the moments, about the gravity axis of the section. This definition assumes that all of the external forces are coplanar, that is, act in one plane. An internal resisting moment at any section is equal to the sum of the moments of the internal stresses about the gravity axis of the section. The external bending moment acting on any section is numerically equal to the

internal resisting moment but acts in the opposite direction. External moments are positive or negative depending upon the direction in which they tend to rotate the section of the beam under consideration. (Cf. **moment**.)

BENEFICIAL OCCUPANCY DATE (BOD). That date when buildings and/or other construction will be completed to a point which will permit occupancy by a unit organization and installation team for the purpose of installing unit equipment and special and/or fixed equipment that is not included as installed equipment. Operational use is possible as soon as unit and special equipment are in place.

BENITO. A continuous wave navigation system measuring range and azimuth from one or more ground stations. The range is determined by a phase comparison method.

BENZENE. An organic compound, having the composition, C_6H_6 . It is an inflammable hydrocarbon of boiling point $176^\circ F$, freezing point $42^\circ F$, and specific gravity 0.879.

BERKELIUM. Radioactive element. Symbol Bk. Atomic Number 97.

BERNOULLI LAW (OR THEOREM). A statement of the law of the conservation of energy for steady flow of an inviscid fluid. If the fluid may be regarded as incompressible, the sum, $p + \frac{1}{2}\rho v^2 + \rho gh$ (where p is local hydrostatic pressure, $\frac{1}{2}\rho v^2$ is the kinetic pressure, and gh is the local gravitational potential), is constant along any one streamline. If the flow is also irrotational, the sum is constant over the whole flow. This law serves to explain the lift of an airplane wing; since the contour is such that the air passing over the wing travels further than that passing below, the velocity of the air above is increased so that its pressure is decreased, producing a lifting effect. The law may be generalized for compressible flow.

BERNOULLI PROBABILITY THEOREM. If the chance of an event occurring upon a single trial is p , and if a number of independent trials is made, the probability that the ratio of the number of successes to the number of trials differs from p by less than any preassigned quantity, however small, can be made as near certain as may be desired by making the number of trials sufficiently large. The theorem may be restated: "If the probability of an event is p , and if an infinity of

trials is undertaken, the proportion of success is sure to be p ."

BERYLLIUM. Metallic element. Symbol Be. Atomic Number 4.

BETA 57-1. The IGY designation for the Sputnik II satellite.

BETA-ABSORPTION GAUGE. An instrument which measures the thickness or density of a sample by measuring the absorption of β -rays in the sample.

BETA DECAY. Beta disintegration.

BETA DISINTEGRATION. A radioactive transformation of a nuclide wherein the atomic number is changed by $+1$ or -1 , and the mass number is unchanged. When the atomic number is increased by 1, negative β -particle emission occurs, and when the atomic number is decreased by 1, there is positive β -particle (positron) emission or electron capture.

BETA DISINTEGRATION ENERGY. (1) The disintegration energy of a beta-decay process; symbol Q_β . For negatron emission it is equal to the sum of the kinetic energies of the β -particle, the neutrino, and the recoil atom (usually negligible), and is obtained experimentally from the maximum energy of the β -particle spectrum. For positron emission, the energy equivalence of two electron rest-masses must be added to the aforementioned sum, since the products include the positron and one negative electron in addition to the neutral product atom, the energy equivalent to their masses ultimately appears as radiant energy of annihilation radiation. For electron capture, the disintegration energy is equal to the sum of the kinetic energy of the neutrino and the electronic excitation energy of the product atom (usually, the binding energy, in the neutral product atom, of an electron equivalent to that which was captured).

(2) Often, implicitly, the ground-state β -disintegration energy, which is the total energy released in a β -transition between isobars in their ground states; symbol $Q_{\beta 0}$. It includes the energies of any γ -radiation and associated radiations following the β -process itself.

BETA-EMITTER. A radionuclide that undergoes disintegration by emission of a β -particle.

BETA PARTICLE. A negative electron or positive electron (positron) emitted from a nucleus undergoing β -disintegration.

BETA RAY. A stream of β -particles.

BETA-RAY SPECTRUM. (1) The distribution in energy or momentum of the β -particles (not including conversion electrons) emitted in a β -decay process. The β -ray spectrum is always continuous up to a maximum energy. Its shape depends upon the nature of the particular β -decay process.

(2) Sometimes, and loosely, the energy spectrum of the electrons emitted by a radioactive source, irrespective of their origin. In addition to the continuous spectrum of definition (1), it may show lines due to internal conversion or to Auger electrons.

BFO. Beat-frequency oscillator. (See Oscillator, Beat-frequency.)

B-H CURVE. Magnetization Curve.

Bi. Bismuth.

BI-APS. Battery inverter accessory power supply.

BIAS. (1) In electrical work this term is used to denote a voltage whose principal function is to locate the operating point on the characteristic of a transducer. The term is most commonly applied in connection with a vacuum tube or transistor. If applied to the grid voltage of a vacuum tube, it means the d-c voltage (other than signal voltage) applied between the cathode and control grid of the tube. In this connection, the term C-bias is also commonly used. The bias may be obtained from a source of d-c voltage, from the potential drop across a resistor (cathode resistor) in the cathode circuit, or when the grid carries current, from the drop across a resistor in the grid circuit. The first method is called "fixed" bias and the latter two, "self" bias. There are actually three forms of fixed bias: battery between cathode and ground, battery between grid and ground, and voltage divider from B+ to ground. Fixed bias arrangements are not usually used in oscillator circuits; these use either cathode bias or grid-leak bias. Cathode bias, sometimes called "self" bias, is applied by means of a resistor between the cathode and ground; the value of which is determined by average current

through the tube. *Grid-leak bias* applies the resistor between the cathode and grid. A corresponding use of the term bias is made in connection with operating points of transistors. (See **Transistor Circuits**.) Bias is also used in telegraphy to indicate undesirable voltage additions to or subtractions from the code signals. (2) In statistical terminology, if t is a static estimating a parameter θ , then the bias of t is defined as $\xi(t) - \theta$ when ξ denotes the expected value. In practical sampling, an estimator that would normally be considered unbiased (such as the sample mean) may become biased due to the method of selecting the samples, or due to systematic errors in the observations. (3) In gunnery, bias is a term denoting the distance from the center of the target to the center of impact of one or a group of rounds. It is not connected with the accuracy of the weapon *per se*, but may be due to mislocation of the target, misorientation of the weapon, windage or other constant errors. The bias is a quantity which must be identified and eliminated from consideration in any determination of accuracy.

BIAS CELL. A small electric cell which is capable of supplying an open-circuit voltage of $1\frac{1}{2}$ or $1\frac{3}{4}$ volts indefinitely.

BIAS WINDINGS. Of a saturable reactor, those control windings by means of which the operating condition is translated by an arbitrary amount.

BICKFORD FUZE. A type of safety fuze. It has a core of black powder enclosed in a protective shield, which often consists of alternate layers of textile and waterproofing material. This fuze is also known as a "miner's" or "safety" fuze; it burns approximately 1 foot per minute and is used for communicating fire.

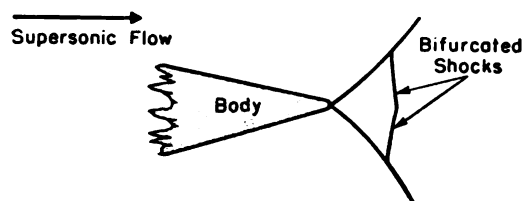
BICONICAL ANTENNA. Antenna, biconical.

BICONVEX. Having a convex surface on both sides. Many lenses and certain supersonic airfoils are biconvex in cross section.

BIDIRECTIONAL PULSE. Pulse, bidirectional.

BIDIRECTIONAL PULSE TRAIN. Pulse train, bidirectional.

BIFURCATED SHOCK. A formation of shock waves characterized by a lambda-shaped branching (λ). It is associated with laminar boundary layer regimes operating in the **transonic range**. (See figure.)



Bifurcated shock pattern.

BILATERAL TRANSDUCER. Transducer, bilateral.

BINARY CELL. In computer work, an information-storing element which can have one or the other of two stable states.

BINARY CODE. A process or means of identifying the digits in a **binary number system**, e.g., pulses varying in duration or spacing.

BINARY-CODED DECIMAL SYSTEM. A system of number representation in which the decimal digits of a number are expressed by binary numbers.

BINARY NUMBER SYSTEM. A number system which uses two symbols (usually denoted by "0" and "1") and has two as its **radix**, just as the decimal system uses ten symbols ("0, 1, . . . 9") and has ten as its radix. This system is widely applied to electronic computation where simple alternatives (i.e. binary conditions) can be reproduced by electrical connections such as a relay open = "0," and closed = "1."

Conversion of decimal to binary numbers. The conversion from decimal to binary numbers is done by successive division by two and reading up the remainder column for the result. For example, to express 13 as a binary number:

$$\begin{array}{rcl} 13 & = & 6 \text{ with a remainder of } 1 \\ 6 & = & 3 \text{ with a remainder of } 0 \\ 3 & = & 1 \text{ with a remainder of } 1 \\ 1 & = & 0 \text{ with a remainder of } 1 \end{array}$$

Reading up the remainder column gives the result, 1101.

Conversion of binary to decimal numbers.

The conversion from binary to decimal numbers is done by multiplying the digits of the number by ascending powers of 2, and adding the result. For example, to express the binary number 1101 in decimal system:

$$\begin{aligned} 1 \times 2^0 &= 1 \\ 0 \times 2^1 &= 0 \\ 1 \times 2^2 &= 4 \\ 1 \times 2^3 &= 8 \end{aligned}$$

Addition gives the result, 13

Binary Arithmetic Addition Rules.

$$\begin{array}{cccc} 0 & 0 & 1 & 1 \\ +0 & +1 & +0 & +1 \\ \hline 0 & 1 & 1 & 10 \end{array} (*)$$

(*) 1 is carried to the next higher ordered column.

For example:

$$\begin{array}{lcl} \text{Augend} & 0111 & = 0 + 4 + 2 + 1 = 7 \\ \text{Addend} & +0100 & = 0 + 4 + 0 + 0 = 4 \\ \hline & 1011 & 0 + 8 + 2 + 1 = 11 \end{array}$$

Mechanically, binary addition can be accomplished in two ways: by the parallel method or the serial method.

Binary Addition, Parallel Method. All columns are added at the same time. It is the faster of the two methods but requires as many sets of carry and sum devices as there are columns to be added.

Binary Addition, Serial Method. This method requires as many pulse periods of time as there are columns of digits. It is the most common method for performing binary addition where time is not important. Numbers are fed into the input as a train of pulses ("0" represented by no pulses, and "1" by the presence of a pulse).

Binary Subtraction

$$\begin{array}{cccc} 0 & 1 & 1 & 0 \\ -0 & -0 & -1 & -1 \\ \hline 0 & 1 & 0 & 0 \end{array} (*)$$

(*) 1 is borrowed from the next higher column.

Example:

$$\begin{array}{r} \text{Minuend} \quad 011101 \\ \text{Subtrahend} \quad -010101 \\ \hline \quad \quad 001000 \end{array}$$

$$\begin{aligned} &= 0 + 16 + 8 + 4 + 0 + 1 = 29 \\ &= -0 - 16 - 0 - 4 - 0 - 1 = -21 \\ &\quad 0 + 0 + 8 + 0 + 0 + 0 = 8 \end{aligned}$$

Binary Multiplication

Example:

$$\begin{array}{rcl} 21 & 1011 & = 11 \\ \times 14 & \times 101 & \times 5 \\ \hline 21 & 1011 & \\ 21 & 0000 & \\ 21 & 1011 & \\ 21 & 110111 & = 55 \\ \hline 21 & & \\ 294 & & \end{array}$$

Binary Division

Example:

$$\begin{array}{rcl} 6 & 000110 & = 6 \\ 7/42 & 7 = 111/101010 & = 42 \end{array}$$

BINAURAL INTENSITY EFFECT. If θ is the angle made with the median plane of the line joining the ears by a line drawn in the apparent direction of a sound source, and if sound of the same frequency and same phase is incident on both ears, then

$$\theta = K \ln \frac{I_L}{I_R}$$

where I_L is the intensity measured at the left ear, and I_R is the intensity measured at the right ear. K is a frequency-dependent constant.

BINDER. A material used in solid **propellants** to give mechanical strength to the grain.

BINDING ENERGY. (1) The energy required to remove a particle or other entity from a system. (See specific entries which follow.) (2) The energy required to disperse a solid into its constituent atoms, against the forces of cohesion.

BINDING ENERGY, ALPHA-PARTICLE.

The energy required to remove an α -particle from a nucleus. For spontaneous α -emitters, it is the negative of the ground state α -disintegration energy. For most light nuclides the α -particle binding energy is positive and is equal to several mev. For nuclides of mass number ~ 125 , it is approximately zero. For nuclides of mass number ~ 150 to 200, it is negative by ~ 1 to 3 mev, but the lifetimes for α -disintegration are generally too long for detection of α -activity. For most nuclides of mass number exceeding 200, the α -particle binding energy is negative by ~ 4 to 8 mev, leading to observable α -activity.

BINDING ENERGY, ELECTRON. The energy necessary to remove an electron from an atom. It is identical with the **ionization potential**.

BINDING ENERGY, ELECTRON, TOTAL. The energy necessary to remove all the electrons from an atom to infinite distances, so that only the nucleus remains. It is equal to the sum of the successive **ionization potentials** of that atom.

BINDING ENERGY, NEUTRON. The energy required to remove a single neutron from a nucleus. Most known neutron binding energies are in the range 5-8 mev, though that for H^2 is 2.23 mev, that for Be^9 is 1.67 mev, and that for C^{12} is 18.7 mev.

BINDING ENERGY, NUCLEAR. The energy that would be necessary to separate an atom of atomic number Z and mass number A into Z hydrogen atoms and $A-Z$ neutrons. This energy is the energy equivalent of the difference between the sum of the masses of the product hydrogen atoms and neutrons, and the mass of the atom; it includes the effect of electronic binding. (See **binding energy, electron, total**.)

BINDING ENERGY, PROTON. The energy necessary to remove a single proton from a nucleus. Most known proton binding energies are in the range 5-12 mev, although that for H^2 is 2.23 mev, that for He^4 is 19.81 mev, and those for Li^5 and Be^9 are negligible.

BINOMIAL DISTRIBUTION. If the probability of an event occurring in a single trial is p , the chance that it occurs exactly n times in m independent trials is

$$P_m(n) = \frac{m!}{n!(m-n)!} p^n (1-p)^{m-n}$$

where $P_m(n)$ is the probability that the event occurs n times in m independent trials, and P is the probability of the event occurring in a single trial.

BINOMIAL THEOREM. A rule for expanding $(x+y)^n$, where n is a positive integer. The result is

$$(x+y)^n = x^n + nx^{n-1}y + \frac{n(n-1)}{2!} x^{n-2}y^2 + \dots + y^n$$

The $(k+1)$ th term is

$$\binom{n}{k} x^{n-k} y^k$$

where $\binom{n}{k}$ is the binomial coefficient.

BIOASTRONAUTICS. **Astronautics** in its relation to biology; the effect upon living organisms of the conditions of space flight (and other phases of astronautics) and the requirements which the biological factors impose upon astronautic operations.

BIODYNAMICS. The study of the effects upon life of motions of bodies and of the forces acting upon bodies in motion, or in process of changing motion.

BIOLOGICAL SHIELD. A shield used to reduce the intensity of radiation transmitted to an amount permissible physiologically.

BIOSATELLITE. A **satellite** designed to carry an animal or plant, or a satellite that carries an animal or plant.

BIOSPHERE. The part of the earth and its atmosphere in which animals and plants live.

BIOT NUMBER. In solid propellant rocket propulsion, a parameter describing the rate of transfer of heat from the center of a burning grain to the outer cylindrical surface. It is given by:

$$\mathfrak{B} = \frac{hR_e}{\lambda}$$

where \mathfrak{B} is the Biot number, h is the heat transfer coefficient, R_e is the external radius of grain, and λ is the thermal conductivity.

BIPROPELLANT. A **rocket propellant** consisting of two unmixed substances fed to the combustion chamber separately.

"Bipropellant" is used attributively in several self-explanatory phrases, such as bipropellant fuel, bipropellant missile, bipropellant rocket engine or motor, bipropellant system, etc.

BIRD. A figurative name for a missile, earth satellite, or other inanimate object that "flies."

BIRD DOG. **Ding-dong**.

BISMUTH. Metallic element. Symbol Bi. Atomic number 83.

BIT (Binary DigIT). A choice between two equiprobable events; the number of elements or marks used to represent each discrete quantity or value in a set of measurements, thereby determining the accuracy of representation, e.g., 10 bits would allow a quantity to be measured or represented to an accuracy of one part in $2^{10} = 1024$. (See also **binary number system**.)

BIZMAC. The Radio Corporation of America, large-capacity computer which is equivalent to the IBM "700" series.

Bk. Berkelium.

BLACK BODY. This term denotes an ideal body which would, if existed, absorb all and reflect none of the radiation falling upon it; its reflectivity would be zero and its absorptivity would be 100%. The chief interest attached to such a body lies in the character of the radiation emitted by it when heated and the laws which govern the relations of the flux density and the spectral energy distribution of that radiation to the temperature.

The total emission of radiant energy from a black body takes place at a rate expressed by the Stefan-Boltzmann (fourth-power) law; while its spectral energy distribution is described by Wien's laws, or more accurately by Planck's distribution law, as well as by a number of other empirical laws and formulae.

The nearest approach to the ideal black body, experimentally, is an almost completely closed cavity in an opaque body. The laboratory type is usually a somewhat elongated, hollow metal cylinder, blackened inside, and completely closed except for a narrow slit in one end.

BLACK BODY RADIATION. Radiation having a spectral distribution of energy according to the Planck distribution law and such as would be given off by an ideal black body or complete radiator. The energy distribution is a function of only the temperature of the radiator.

BLACK BOX. (1) A term used loosely to refer to any sub-component that is equipped with "connects" and "disconnects" so that it can be readily inserted or removed from a specified place in a larger system (e.g., the complete missile, or some major subdivision) without benefit of knowledge of its detailed in-

ternal structure. (2) A term pertaining either to the functional transformation that acts upon a specified input to give a particular output, or to the apparatus for accomplishing this transformation (without regard to the detailed circuitry used).

BLACK KNIGHT. A United Kingdom liquid propellant rocket given publicity in 1958. It was fired from Woomera, Australia and claimed to have reached an altitude of 400 miles. It was reported to be a medium-range surface-to-surface missile.

BLACK POWDER. Gunpowder.

BLACKOUT. (1) A condition in which vision is temporarily obscured by a blackness, accompanied by a dullness of certain of the other senses, brought on by decreased blood pressure in the head and a consequent lack of oxygen, as may occur, e.g., in pulling out of a high-speed dive in an airplane. This condition is sometimes followed by a loss of consciousness, but the unconsciousness is not usually regarded as a part of the blackout. (Cf. **grayout**, **red-out**.) (2) In radio, a condition brought on by natural causes not owing to malfunctioning equipment, in which radio-receiving sets fail to pick up signals.

BLANKING SIGNAL. A wave constituted of recurrent pulses, related in time to the scanning process, used to effect blanking. In television, this signal is composed of pulses at line and field frequencies, which usually originate in a central sync generator and are combined with the picture signal at the pick-up equipment in order to form the blanked picture signal. The addition of the sync signal completes the composite picture signal. The blanking portion of the composite picture signal is intended primarily to make the return trace on a picture tube invisible. The same blanking pulses or others of somewhat shorter duration are usually used to blank the pickup device also. (See **pulses**, **blanking**.)

BLAST. The brief and rapid increase in air pressure resulting from the detonation of any explosive matter.

BLAST CHAMBER. A combustion chamber, especially a combustion chamber in a gas-turbine engine, jet engine, or rocket engine.

BLAST CLUSTER WARHEAD. Warhead, blast cluster.

BLAST DEFLECTOR. A deflector used to divert the blast of a rocket fired from a vertical position.

BLAST-OFF. A colloquial expression for the take-off of a missile or rocket.

BLAST WARHEAD. Warhead, blast.

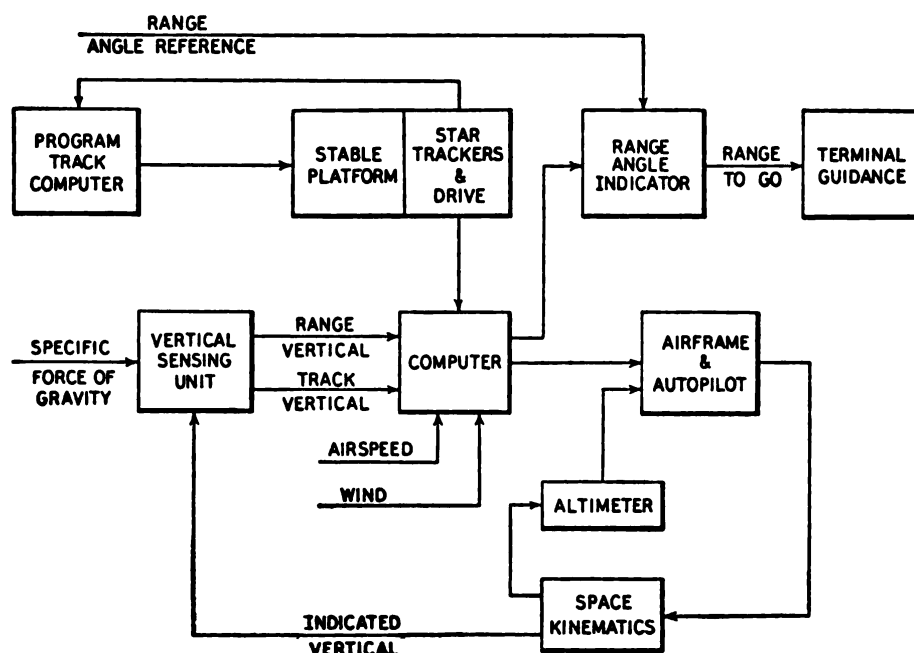
BLEED. The intentional allowance of leakage from hydraulic or pneumatic lines for the purpose of permitting the working fluid to fill reservoirs, valves, pipes, etc., so as to maintain proper working conditions throughout the system. In hydraulic systems, bleeding prevents air lock and bubbling.

BLEEDER RESISTOR. A resistor used to dissipate the charge of a capacitor after the

an echo appearing on a sweep type presentation.

BLISTER. (1) Colloquialism for a radome. (2) A protuberance on the skin of a missile, used as a housing for electrical cables.

BLOCK DIAGRAM. A graphical method of presenting the functional units of a complex circuit or machine. Each important unit of the device is drawn in the form of a non-dimensional rectangle in which is inserted the name of the unit and perhaps some additional information about its functioning such as inputs, outputs, number of stages, amplification, etc. These "blocks" are then connected with lines to show interconnections and relationships with other units in the whole system. It may be a circuit diagram showing functional circuit elements without details. (See figure.)



Block diagram of inertial-celestial guidance system.

power has been disconnected. It may be used for such safety purposes as to protect electronic components from damaging voltages under reduced loads.

BLIP. A streak of light on a radar screen caused by an object or some electronic disturbance in the path of the radar beam. It is the same as a "pip" but is normally applied to

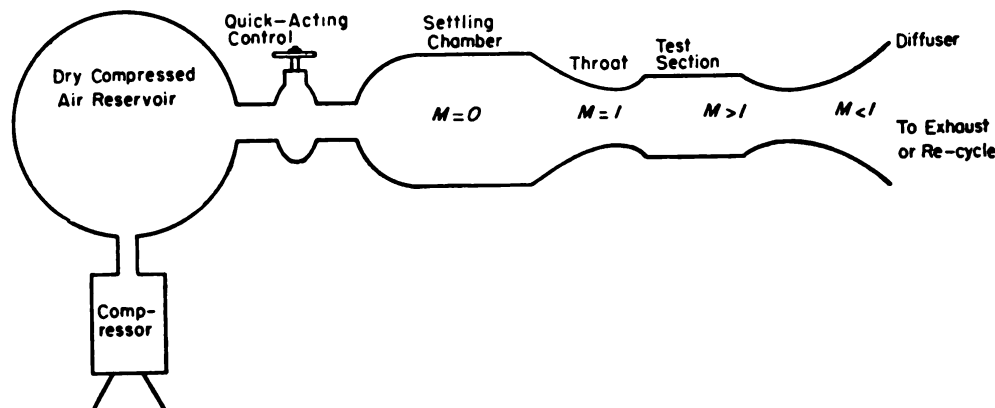
BLOCKHOUSE. A building, usually heavily reinforced and near the launching site, that houses the electronic equipment and controls for preparation and firing of a missile, together with its auxiliary apparatus. Blockhouses are normally designed to withstand the nearby blast of a weight of TNT somewhat less than the load of propellant carried in the missiles to be fired. Theoretically this design factor

should protect occupants in case the missile falls back on the pad and explodes.

BLOCKING. The interruption of **plate current** in a tube due to the application of a high negative voltage. When done intentionally, this may be called blanking or gating.

BLOCKING CAPACITOR (or Condenser). Any capacitor used in a radio circuit to block the flow of direct current while allowing alternating current signals to pass.

downstream sides of the test section. The atmosphere may be used as either the upstream or downstream reservoir. The chief advantage of this type of wind tunnel is that the low pressure reservoir may be evacuated (or the high pressure reservoir pumped up), over a long period of time. This allows low power sources to be used. It is cheap and simple, but its runs are of limited duration and there is a continuous variation of total pressure and temperature during each run. (See figure.)



Blow-down wind tunnel.

BLOCKING OSCILLATOR. Oscillator, blocking.

BLOODHOUND. A British ground-to-air missile manufactured by the Bristol Aeroplane Company. The missile has been under development since 1949. Ferranti Limited produces the guidance system. Sustainer power is from two Bristol *Thor* ramjets. Boost power comes from 4 solid propellant rockets in "wrap-around" configuration at the tail. The missile is cylindrical, blunt-tailed, ogival nosed, and has tapered stubby wings with raked tips. It uses one *Thor* above and the other below on small pylons. The position of the ramjets prevents having any vertical surfaces and the missile must be rolled into a bank and pitched by elevator action. Roll is achieved by differential displacement of the wing pitch. The missile is about 1½ feet in diameter, 22 feet long and has a 9 foot span. It uses a radar command type of guidance.

BLOW-DOWN WIND TUNNEL. A supersonic blow-down wind tunnel uses an air supply system which creates a pressure differential from the upstream (high pressure) to the

BLOW-OUT DISC. A mechanism consisting generally of a thin metal diaphragm, used in a solid rocket as a safety measure against excess gas pressure in the combustion chamber.

BLUE PHONE LINE. A party line telephone system which provides a link between personnel involved in countdown procedure. All conversations are tape recorded.

BLUE STREAK. A British IRBM, liquid propellant missile, developed under a prime contract by De Havilland Propellers Ltd.

BLUFF BODY. In aerodynamics, a non-streamlined body, or a body of low **fineness ratio**.

BMD. Ballistic Missiles Division, Air Research and Development Command/Formerly designated WDD (Western Development Division)/; Los Angeles, California.

BMEWS. Ballistic Missile early warning system.

BMO. Ballistic Missiles Office, Air Materiel Command.

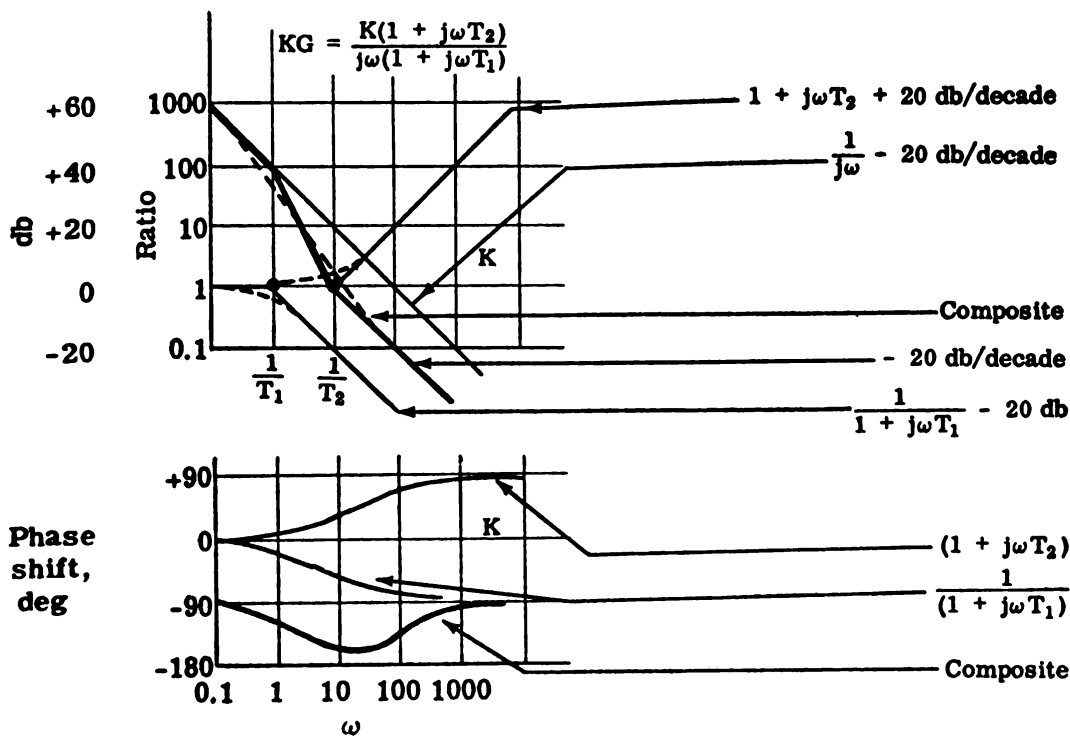
BOA. Broad ocean area.

BOATTAIL. The cylindrical section of a missile body in which the diameter is continually decreasing toward the rear. The principal purpose of a boattail is to reduce the over-all aerodynamic drag of a missile airframe. However, boattailing has the undesirable effect of decreasing tail drag and stability, and in some vertically-launched missiles, requiring tail fins to support the missile prior to take-off. Boattailing is therefore seldom applied to such missiles. It is frequently encountered in aerodynamic-type missiles because of the smoother air-flow which it produces.

BOBBIN. A British Rockoon type system.

BOD. Beneficial occupancy date; usually referring to a facility under construction.

BODE CHART (or Diagram). A plot of phase versus frequency or gain versus frequency to describe the frequency response characteristics of an amplifier, servo or other device. (See figure.)



Bode diagram of the open-loop transfer function, KG , shows magnitude and phase shift of the individual terms in the function. Adding the individual line segments produces the composite response for KG (heavy lines). Solid lines indicate approximate (asymptotic) response of the terms while the dashed lines represent the true response.

BODY HARDWARE. Fittings and parts connected to the airframe and usually part of the airframe assembly.

BODY LIFT. Aerodynamic lift on a fuselage or missile body varying with an angle of attack of the body.

BODY-MOUNTED GYROSCOPE. A gyroscope mounted directly on the airframe, thus using it as a reference instead of a stabilized platform.

BOGEY WEIGHT. Weight, bogey.

BOILER PLATE. (1) A general term for metal plate having a thickness of $\frac{3}{16}$ " or greater. Flat metal of lesser thickness is usually called sheet. (2) Colloquial term for highly standardized language found in missile specifications and contracts.

BOILING OF BODY FLUIDS. A phenomenon which may occur when the external pressure of an animal is reduced to the vapor pressure of the body fluids at that temperature (about 47 mm at normal human temperature (98.6°F)).

BOILING POINT. The normal boiling point of a liquid is the temperature at which its maximum or "saturated" vapor pressure is equal to the normal atmospheric pressure, 760 mm of mercury. If the pressure on the liquid varies, the actual boiling point varies in accordance with the relation between the vapor pressure and the temperature for the liquid in question. (See **vapors**.) Water, for example, with a normal boiling point of 100°C or 212°F, boils at ordinary room temperature when the pressure is reduced to about 17 mm. If a solid is dissolved in the liquid, or if another, less volatile liquid is mixed with it, the boiling point is raised to a degree expressed by the boiling point laws of van't Hoff, Raoult, and others.

BOLD ORION. An air-to-ground missile to be developed by the U.S. Air Force with funds budgeted in Fiscal Year 1960. With a reported range of 1000 miles it will permit bombers to strike strategic targets without penetrating the most heavily defended areas. The missile will probably be boost-glide or ballistic in its trajectory.

BOIL-OFF. The vapor loss from any volatile liquid, e.g., liquid oxygen; particularly when stored in a missile ready for flight.

BOLOMETER. (1) A very sensitive type of metallic resistance **thermometer**, used for measurements of thermal radiation. (See **detector, infrared**.) (2) In electronics, a small resistive element capable of dissipating microwave power, and using the heat so developed to effect a change in its resistance, thus serving as an indicator; commonly used as a detector in a low, and medium, level power measurement. Bolometers and crystals are used as detectors in microwave antenna measurements. The bolometer has a coverage over a larger range of power than a crystal; crystals are more sensitive but tend to be less linear in response. A bolometer can also be used to measure the standing wave ratio of a given radiation. Bolometers are also called "bareters" and "thermistors."

BOLTZMANN CONSTANT. The constant k in the calculations arising in the development of the **Boltzmann principle**. The least squares adjusted output value of this constant is

$$(1.38026 \pm 0.000022) \times 10^{-16} \text{ erg deg C}^{-1}.$$

The Boltzmann constant is equal to the **ideal gas constant** per mole (R) divided by the **Avogadro number**.

BOMARC. A U.S. Air Defense Command surface-to-air, supersonic (to Mach 3) interceptor missile, developed by the Boeing Airplane Company. The operational vehicle cruises on twin Marquardt ramjets. Its range is 200-300 miles, its ceiling, over 68,000 ft.; its launch weight, 15,000 lb., using solid propellants. Its guidance is ground-controlled through SAGE system and by ground-controlled Westinghouse Electric homing radar. Its span is 18 ft. 2 in.; and its length, 46 ft. 10 in. (See **missile, guided**.) (See illustration facing Page 58.)

BONDED GRAIN, CASE. Grain, case-bonded.

BONDERIZED STEEL. Steel protected against corrosion by a coating produced on the surface by heating in an air-tight container filled with a mixture containing phosphorous acid, varnish, etc.

BONDING. The practice of adding electrical connections between metallic parts of an entity, such as railway track, a vehicle, etc., so as to form a continuous electrical pathway. A good bond should have approximately the same electrical resistance that would exist if the parts were integral. Bonding is used on vehicles to prevent electrical interference with radio equipment, and to reduce the danger of fires caused by sparks arcing between unconnected metal parts upon which static or r-f voltages have developed. Arcing becomes more and more of a problem as the air pressure decreases with altitude. Other reasons for bonding are to reduce radio frequency interference by connecting all shielding elements together so as to offer a low r-f impedance, and to provide antenna counterpoise by connecting all exterior surfaces together.

BONNER DURCHMUSTERUNG. The name Bonner Durchmusterung is applied to the monumental catalogue of 324,198 stars observed by that tireless observer F. W. A. Argelander. Accompanying the catalogue is an atlas of the heavens upon which each of the catalogued stars is shown by a dot, the size of the dot being proportional to the apparent brightness of the star. The catalogue contains practically every star brighter than the tenth

magnitude north of declination -2° . The catalogue is commonly referred to as the B.D. and in many astronomical writings a particular star is referred to by its B.D. number (i.e., by the number assigned to it in the Bonner Durchmusterung).

The catalogue was continued by Schonfeld down to declination -23° , and Thome at Cordoba has extended it still further to -61° . It is hoped that the plan will be continued to the south pole.

In each of the catalogues stars are numbered in order of increasing **right ascension** within a particular zone of declination. Hence, a star known as CDM -48 1116 is the 1116th star in the Cordoba extension of the B.D. catalogue between declination -48° and -49° .

BOOST. To increase or amplify.

BOOSTER. (1) In warheads, a high-explosive element sufficiently sensitive to be actuated by small explosive elements in a fuze and powerful enough to cause detonation of the main explosive filling. (British-Gaine.) (2) In the launching system, an auxiliary propulsion system which travels with the missile and which may or may not separate from the missile when its impulse has been delivered. A booster system may contain or consist of one or more units. (See **Jato**.) (3) An electrical booster is one of several types of devices inserted in series in an **electric circuit**, to increase the **voltage**.

BOOSTER ASSEMBLY. The structure which is used with some missile types to support one or more **Jatos**, transmit the thrust to the missile, and orient the thrust line with respect to the center of gravity of the combination.

BOOSTER IMPACT AREA. The area, downrange and along the line of flight, where **booster rockets** strike the surface of the earth after having been detached from a missile at staging or end of boost phase.

BOOSTER ROCKET. (1) A **rocket** that supplies temporary additional thrust to an aircraft, missile, or the like having other means of propulsion. A **RATO** unit is one kind of booster rocket. (2) A rocket used to increase the altitude, speed, or range of another rocket or missile. Boosters are used to

attain speeds required for initiation of ramjet engine operation, provide rapid accelerations, assist in takeoff, etc. The initial stage of any two (or more) stage missiles is termed the booster.

BOOTES. (The herdsman). While not in the zodiac, Bootes is one of the earliest recorded **constellations**. It is readily recognized in the early summer skies from the kite-shaped configuration of stars with the bright star Arcturus at the position of the tail of the kite.

The star Arcturus is the fourth brightest star visible in the northern latitudes. It is also a very interesting star from the astronomical point of view, being what is known as a **giant** star. In appearance the star is a red-dish-yellow and the **spectral type** is such as to indicate that its temperature is slightly lower than that of the sun. Its angular diameter has been very carefully determined, and, since its distance is known, we find its linear diameter to be about 27 times that of the sun.

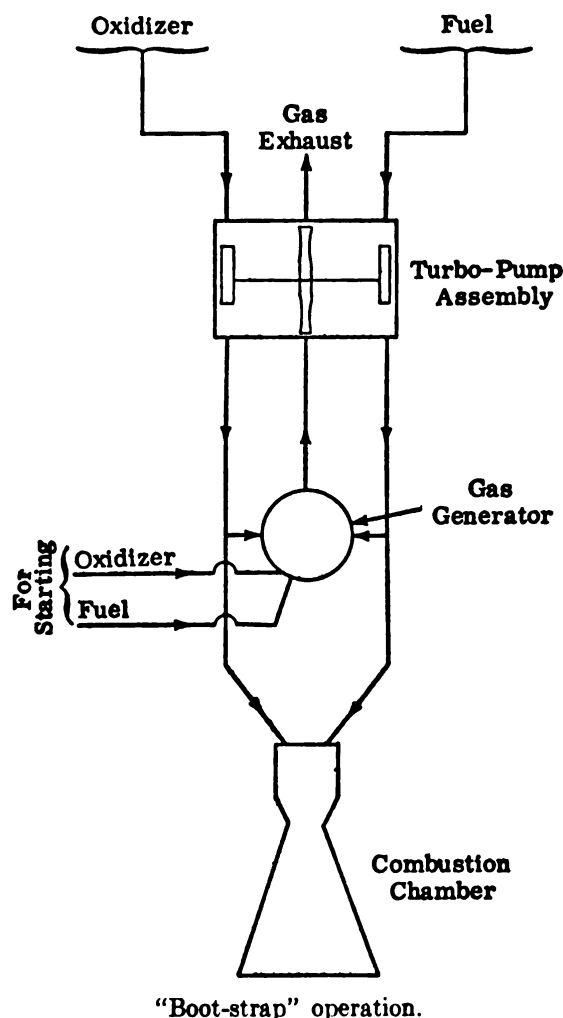
Many of the other brighter stars in Bootes are **double stars**, several of them forming interesting objects of study with relatively small instruments.

BOOTSTRAP. In general, a physical quantity such as the pressure in a system, which is maintained by a cyclic or **feedback** process within the system.

"BOOT-STRAP" OPERATION. In liquid rocket engine usage, a regenerative process used for starting. A portion of the turbopump output is fed back to the gas generator which causes an increase in available energy for driving the turbopump, which in turn delivers a greater quantity of propellants to the gas generator. The cycle terminates when rated system performance has been attained. (See figure on Page 98.)

BORANE. A suffix used to denote a compound of boron and hydrogen. Thus tetraborane is B_4H_{10} , a liquid boiling at $16^\circ C$; pentaborane is B_5H_9 , and decaborane is $B_{10}H_{14}$. These compounds are used in **high energy fuels** for jet engines, and sometimes as **propellants**. (See also **Zip Fuel**.)

BORAZON. A trade name of the General Electric Company for a boron-nitrogen com-



pound (cubic boron nitride) of great hardness and heat-resisting characteristics.

BORESIGHTING. (1) A process whereby a secondary instrument of some sort is mounted to operate along the axis of the primary instrument to which it is attached. For example, a radar boresight camera would be one mounted to take pictures along the axis of the radar beam. The camera views through a small hole in the parabolic reflector or from a suitably placed parallel-mounting. (2) The process of aligning an instrument or piece of ordnance by causing its mechanical axis to coincide with its optical axis, or its electrical axis to coincide with its optical axis. In the case of a gun, the tube is aligned on some distant aiming point, and then the gun pointing devices are adjusted to coincide.

BORESIGHT TOWER. A tower on which there are mounted a visual target and an elec-

trical target (an antenna fed from a signal generator); these targets are used for the parallel alignment of the electrical axis of a receiving antenna and the optical axis of a telescope mounted on the antenna.

BORON. Non-metallic element. Symbol B. Atomic Number 5. (See also **Borane**.)

BORZOI. A British research rocket.

BOUNDARY LAYER. In aerodynamics, the thin region of nearly static fluid near the surface over which the fluid stream is moving. Within the boundary layer the fluid velocity ranges from zero at the body surface to free-stream velocity a short distance away. In most fluid flows at high speed the flow can be considered as non-viscous except in thin layers close to the surface of the body immersed in the fluid. These thin layers, in which the velocity is retarded by friction, are called the boundary layers. Within this layer disturbance waves in the flow due to sudden changes in velocity, pressure and density occur. The impact pressure is reduced as a result of the viscosity of the fluid, determining whether the flow in the boundary layer is smooth ("laminar") or ("turbulent"). In supersonic aerodynamics, the boundary layer has great influence upon the performance of the vehicle. Frictional effects develop from the viscosity of the fluid in contact with the body surfaces. At transonic speeds the boundary layer effects are controlled by attempting to design for laminar flow conditions. In supersonic conditions the formation of shock waves cause the boundary layer to thicken at the point of contact with the shock wave and aerodynamic pressure can be transmitted forward through the boundary layer. Boundary layer effects and shock waves are present side-by-side in supersonic flow and their effects contribute to each other. In designing for supersonic flow it is the objective to obtain laminar boundary layer flow to give the smallest possible skin friction. Turbulent boundary layers have transverse motion of the air within them; this transverse motion allows a greater amount of momentum to be transferred from the solid boundary layer to the free stream. Thus, the skin friction is greater than in the case of laminar flow. Under the turbulent region of a boundary layer there is a very thin region called the "viscous sublayer" where the airflow ap-

proaches the laminar form. If the roughness of the surface over which the air flows is entirely within the viscous sublayer and does not protrude into the turbulent part, there is no effect upon the skin friction. If the surface is rough the turbulent layer is increased, and skin friction is greater. In any accelerating airflow the boundary layer is relatively stable (e.g., a continuously accelerating missile) but in a violently decelerating flow an adverse pressure gradient is encountered and the flow does not remain intact. Boundary layer effects are being investigated continuously but are not fully understood.

In general, there are four types of boundary layers: (1) *Laminar*, where each layer of air glides smoothly over those adjacent to it. (2) *Turbulent*, in which there is transverse motion of the air. (3) *Laminar Separation*, which occurs mainly at low Reynolds numbers and may invalidate tests in small wind tunnels. In it a laminar boundary layer leaves the surface and becomes a part of the free stream. It is uncommon in free flight tests. (4) *Breakaway*, which is the result of a turbulent boundary layer leaving the surface and becoming a part of the free stream. The space between the separated boundary layer and the surface is filled with a turbulent mass of stagnant air, in which there is considerable motion in the direction opposite to the direction of flow. Breakaway is sometimes referred to as "separation" or "flow separation." A boundary layer is very sensitive to adverse pressure gradients. A shock wave is an adverse pressure gradient presenting a pressure discontinuity. A very small shock wave is sufficient to disturb the flow over an entire wing surface behind it, owing to this sensitivity. Great drag (i.e., "shock-drag") situations occur—even flow reversal can be experienced.

BOUNDARY LAYER CONTROL. Any of many techniques applied to airframes to reduce the deleterious effects of unfavorable boundary layer flow conditions. They are usually intended to decrease the drag or increase lift of the areas so treated. In aircraft boundary layer control techniques are applied to subsonic surfaces to reduce take-off runs, decrease take-off and landing speeds, or to decrease aerodynamic buffeting at high supersonic speeds. One form of this technique uses forced circulation which increases the air-

flow over lifting surfaces to stimulate greater air speeds, thus maintaining lower actual ground speeds. Specially designed propellers or flaps to churn larger masses of air against surfaces, "Venetian-blind" type surfaces, or ducted wing sections are typical examples as found in STOL aircraft.

BOUNDARY LAYER, FLUID FLOW. Motion of a fluid of low viscosity, such as air or water, around a stationary body or through a stationary conduit possesses the free velocity of an ideal fluid everywhere except in an extremely thin layer immediately next to the stationary body. Many of the phenomena of fluid flow may be studied and analyzed without consideration of this boundary layer, but, thin as it may be (usually a few thousandths of an inch), its internal mechanics must be understood and evaluated in certain of the phenomena of fluid motion. Some of the more important of these are:

1. The magnitude of the maximum lift coefficient of the airfoils.
2. Profile drag of airfoils.
3. The drag of bluff bodies.
4. The large variations of drag coefficient at critical Reynolds number for laminar-turbulent transition.
5. The transfer of heat through surface films.

BOURDON PRESSURE GAUGE. A pressure gauge consisting of a hollow oval tube, bent into the shape of a shepherd's crook, sealed at the end of the crook. One end is anchored while the crooked end is free to move. The anchored end is connected to the region of the pressure to be measured, and the mechanical uncoiling of the free end of the tube indicates the pressure, usually by an indicator on a dial.

BOURRELET. The front bearing surface of a projectile. It is slightly raised from the body and is an accurately machined diameter which just fits the diameter of the bore. The bourrelet and the rotating band are the two contact points of the projectile with the bore. They are of soft metal.

BOWEN CAMERAS. Ballistic cameras of various types manufactured by I. S. Bowen. In particular the *Bowen ribbon-frame cameras* have been widely used in missile flight test measuring schemes. The ribbon-frame cam-

eras can be used to determine speed and flight path information. Two cameras (or more) are required to be used together with accurate timing coordination, precise orientation and rapid film speeds. They will then give position, velocity, acceleration and attitude information for short portions of the flight line. Since these cameras are fixed so as to cover restricted portions of the flight, they are frequently used in pairs, one overlapping its partner and each working with one of another overlapping pair of cameras at the end of a suitable baseline. Among the Bowen type cameras are: **RC-2** and the **CZR**. Bowens operate at 30, 60, 120 or 180 fps.

BOWEN-KNAPP CAMERA. A very high speed, strip film ballistic camera used for missile flight test documentation. It is usually placed 1 mile or so to the flank of missile launching sites; in such locations they will cover 3-5,000 feet of the flight.

"BOX-CAR" LENGTHENER. A pulse-lengthening circuit which lengthens a series of pulses without changing their height. Ideally, it produces flat-topped pulses prolonged throughout the interval between pulses.

BOYLE-CHARLES LAW. The Boyle law expresses the variation of pressure and volume of a body of ideal gas at constant temperature; the Charles law expresses the proportionality of pressure to absolute temperature (at constant volume), while the Gay-Lussac law states the proportionality of volume to absolute temperature (at constant pressure).

A single statement covering all these relationships is the Boyle-Charles law, which leads to, or is a form of, the ideal gas law. Its mathematical expression may be written:

$$pv = p_0v_0(1 + at),$$

in which p_0v_0 is the value of pv at temperature $t = 0$, and a is the volume coefficient of expansion for the gas in question. If the centigrade scale is used, a is for all gases approximately equal to $\frac{1}{273}$ or 0.003663 per centigrade degree. All real gases depart somewhat from the Boyle-Charles law (ideal gas law). (See equation of state.)

BOYLE LAW. (Mariotte law, law of Boyle-Mariotte.) At constant temperature the volume of a gas varies inversely as the pressure,

and the pressure varies inversely as the volume. In other words, the product of the pressure and volume of a gas is constant at a given temperature. This law holds only for the ideal or perfect gas; all real gases depart from it to a greater or lesser extent. (See equation of state.)

Br. Bromine.

BRACHYDROMIC. A seldom-used term meaning to head short, usually referring to a target. The course of a missile which is heading to pass in the wake of a moving target would be described as brachydromic.

BRAKE HORSEPOWER. The mechanical output of an engine, turbine, or motor is called the brake horsepower because one of the most common methods of testing for mechanical output is with the Prony brake. However, the output available at the shaft is called brake horsepower whether measured by brake or not.

BRAKING ORBIT. A flight path which employs a spiral orbit of diminishing diameter for the purpose of making use of the earth's atmosphere to slow down a spaceship returning from a voyage. The ship dives into the atmosphere allowing friction to slow it down. If frictional heating becomes excessive, theoretically the ship would move out of the atmosphere and re-enter later. The firing of a retro-rocket may be a more practical solution for dissipating orbital energy.

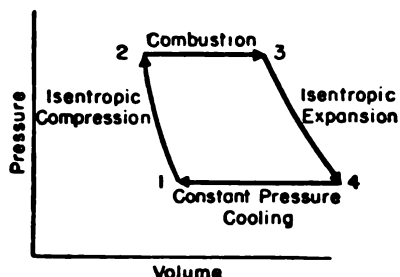
BRAKING ROCKET. A rocket fitted on or in an aircraft, missile, or the like that discharges counter to the direction of flight, used to retard forward motion. Also called a "retro-rocket."

BRANCH. In ballistics, a part of the trajectory, e.g., the ascending or descending branch.

BRANE. A composite word derived from *Bombing Radar Navigation Equipment*. It was a system developed by International Business Machines Corp. in 1955, for installation in B-52 bombers.

BRASS. An alloy in which copper and zinc are the chief constituents, although some such alloys, when hardened by addition of other elements, are classed with the bronzes.

BRAYTON CYCLE. An open cycle as shown in the figure, consisting of isentropic air compression, constant pressure heating, isentropic expansion, followed by constant pressure cooling. This cycle is used in ramjets.



P-V diagram of Brayton cycle.

BRAZING. A method of joining metal parts by heating them and applying at the heated point a molten alloy, which once consisted of copper, tin and zinc; other compositions are now used also.

BREAD-BOARD SET-UP (EQUIPMENT). In electronics, an experimental set-up of a circuit or equipment. Frequently a circuit is wired on a wooden board rather than a regular metal chassis, hence the name. The objective of a bread-board is to permit checking of functions and facilitate experimental changes.

BREAKAWAY. A boundary layer (in a flowing fluid stream) which separates from the surface and becomes part of the free stream.

BREAKDOWN VOLTAGE. The voltage necessary to cause the passage of appreciable electric current without a connecting conductor. It is commonly used to express the voltage at which an insulator or insulating material fails to withstand the voltage and ceases to behave as an insulator.

BREAKWIRE. A trailing cable, usually connected to the tail of a missile, which is the last connection of the missile with ground control. The wire breaks contact after the take-off of the missile. It may be used for any number of purposes until it breaks free, such as: guidance, internal functions monitoring, safety motor cut-off and transmission of take-off power.

BREEDING. The process whereby a fissionable atomic species is utilized as a source of

neutrons to produce more nuclei of its own kind. This is the function of a breeder nuclear reactor.

BREGUET FORMULA. A formula for estimating the range of an aircraft from known aerodynamic parameters. It is

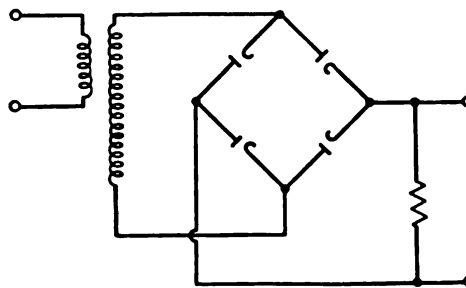
$$R = \frac{LV}{D(SFC)} \ln (W_o/W_e)$$

where R is the range in miles, L is the lift, D is the drag, V is the velocity in miles per hour, SFC is the specific fuel consumption, W_o is the initial loaded weight, and W_e is the final empty weight. (Note: SFC is measured in lbs of fuel per pound of thrust per hour.)

BRENNSCHLUSS. A German word meaning "end of burning" applied to combustion in rockets. (See **burn-out**, **cut-off**, and **shut-off**.)

BRIDGE, ELECTRICAL. (1) A type of connection between two circuits or networks. There are a variety of bridging circuits such as capacitance-resistance, capacitance-inductance-resistance, magnetic sorting, capacitive-conductance bridges, the names of which describe either the electrical quantity bridged or the electrical quantity actuating the bridge. (2) One of a variety of electric networks, one branch of which, the "bridge" proper, connects two points of equal potential and hence carries no current when the circuit is properly adjusted or "balanced." (See figure in article on **Bridge**, **Wheatstone**.)

BRIDGE RECTIFIER. A type of full-wave rectifier. The bridge rectifier will produce a maximum d-c output equal to the peak voltage across the entire secondary. Thus its main advantage is that all the voltage of the secondary is rectified. Its disadvantage is that it requires four diodes. (See figure.)



Bridge rectifier circuit.

BRIDGE, WHEATSTONE. One of the simplest and best-known bridge networks for measuring electrical resistances. Referring to Fig. 1, let R_1 be the unknown resistance and R_2 a known resistance, preferably not very different from R_1 , in terms of which R_1 is to be measured. R_3 and R_4 , called the ratio arms, are two other resistances which may be varied continuously or by very small stages and the values of which are known, either in ohms or relatively to each other. From C to D is the bridge proper, containing a galvanometer. To measure R_1 , the resistances R_3 and

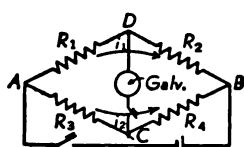


Fig. 1

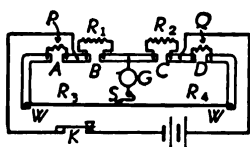


Fig. 2

Sketches of simple and four-gap Wheatstone bridge circuits.

R_4 are adjusted until the galvanometer shows no current, which means that C and D are at the same potential. It then readily follows from the law of potential drop that $R_1:R_2 = R_3:R_4$, and hence $R_1 = R_2R_3/R_4$. Fig. 2 shows a "slide-wire" form having a graduated resistance wire and four gaps. The Carey-Foster bridge is a special type of Wheatstone bridge.

BRINELL HARDNESS. A measure of the hardness of a material, in terms of a specified indentation procedure. The indenter is 10-millimeter hardened steel ball. A sintered tungsten-carbide ball is also coming into use, especially for testing hard metals. The load applied is generally 500 kg. for soft metals and 3000 kg. for steels and hard metals. Brinell hardness is equal to the load (kg.) divided

REPRESENTATIVE BRINELL HARDNESS NUMBERS

Material	500 kg Load	3000 kg Load
Aluminum	23	
Magnesium alloy	63	
Brass	72	83
Iron	66	73
Copper	99	83
Mild steel	107	117
Molybdenum steel		241-263
Tool steel		684

by the surface area (sq.mm.) of the impression made in the test material. Tables are available for direct conversion to hardness from the diameter of the indentation as measured with a calibrated magnifier after removal of the piece from the testing machine.

BRISANCE. The shattering effect of an explosion.

BRITISH INTERPLANETARY SOCIETY. A British organization of scientific workers active by vocation or avocation in solving or discussing the problems of space flight.

BRITISH SYSTEM OF UNITS. Units and dimensions.

BRITISH THERMAL UNIT. Unit of work or energy, abbreviated BTU. The energy required to raise the temperature of one pound of water through a temperature rise of one degree Fahrenheit without any vaporization. When greater precision is needed, the temperature rise is specified as from 39°F to 40°F. One British thermal unit is equal to about 252 calories.

BROADSIDE ARRAY. Antenna array, broadside.

BROMINE. Non-metallic liquid element. Symbol Br. Atomic number 35.

BRONZE. Originally an alloy consisting chiefly of copper and tin, although the term has been extended to many copper alloys having properties similar to those of the bronzes, but in which the tin has been replaced entirely by other alloying elements. The bronzes have good corrosion resistance as compared with other common alloys. Addition of phosphorus, silicon or aluminum is particularly beneficial to the corrosion resistance.

BROWNIAN MOVEMENT. The irregular and random movement of small particles suspended in a fluid, discovered by Robert Brown in 1827, and now known to be a consequence of the thermal motion of fluid molecules. The motion is caused by statistical fluctuations of pressure over the surface of the particle and the distribution of particle velocity is similar to that of a gas molecule of the same weight as the particle.

BROWN RECORDER. A number of types of recording instruments are manufactured

under this name by the Minneapolis Honeywell Regulator Co. A type that is used widely in aeronautical and astronautical work consists essentially of a sensitive galvanometer whose indicating arm is a reservoir type pen which touches and marks on a roll of grid paper moving at a fixed speed. The recorder is also equipped with a second marking pen operating on one edge, which can be rigged to record by small coded pips the timing of the trace. It is not capable of recording high frequency phenomena as well as the **oscillograph**.

BRUSH. A device for conducting current to or from a rotating part. The brush is stationary, and is held and guided by a fixed brush holder in which it slides freely. There may be several brushes side by side to form a single-brush set. The rotating member may be the commutator of a d-c generator or motor, or it may be the slip rings of an a-c motor or generator. Other examples of brushes are those used in magnetos and static electricity machines.

BRUSH RECORDER. The brand name of a type of recording device consisting of a gridded moving paper roll passing under a stylus pen which is attached to the end of a **galvanometer**. The stylus brushes against a pressure sensitive paper which shows a carbon interior (as a black line on a silver background) when marked by the pen. One to twenty such pens can be mounted on a single recording instrument. A common brush recorder is the dual-channel recorder, wherein the paper tape passes across one end where it is displayed under a small glass viewing window. Dual-channel recorders permit the recording of one variable against another. The **oscillograph** is preferable for recording high frequency phenomena.

BSE. Base support equipment.

B-SCOPE. A **radarscope** that presents the range of an object by a vertical deflection of the signal on the screen and bearing by a horizontal deflection.

BTL. Bell Telephone Laboratories.

BTZ. A series of French army missiles developed by the Bureau Technique Zbrowski in Brunoy, Seine et Oise, France. Among

them are: BTZ 412-01, (Ogre I); BTZ 411-01, (Lutin); and the BTZ 420-01, (Naine Bébé).

BuAer. Department of the Navy, Bureau of Aeronautics.

BUBBLE HORIZON. (1) A circle on the celestial sphere parallel to the **celestial horizon**, formed by the intersection of the sphere with the plane of the sensible horizon as established by a **bubble sextant**. (2) The plane established by a bubble sextant, otherwise called the "sensible horizon."

BUBBLE SEXTANT. A sextant that measures angular altitudes above the plane of the sensible horizon as established by a bubble set into a field.

BUCKET. (1) One blade of a turbine. (2) In missile slang "in the bucket" means that the missile fell within allowable limits of the target point.

BUFFER. (1) An isolating circuit used to avoid reaction of a driven circuit on the corresponding driving circuit. (2) A storage device used to compensate for a difference in rate of flow of information, or time of occurrence of events when transmitting information from one device to another.

BUFFER AMPLIFIER. One or more stages of RF amplification used in a transmitter to build up the control crystal frequency to an appropriate level before modulation. This is to prevent feedback of undesired frequencies to the crystal.

BUFFER CONDENSER. Any condenser connected in an electronic circuit for the purpose of reducing peak or surge voltage amplitude to protect other parts in the same or following circuits.

BUFFER STAGE. An amplifier stage used to prevent feedback of energy from a power stage to a preceding stage.

BUFFETING. In aerodynamics, the irregular repeated forces on an airfoil or airframe member due to the recurring encounters with air flow disturbances. Buffeting causes additional stress. It may be due to meteorological conditions, maneuvers of the vehicle, or airflow conditions deriving from its speed. It is caused by sustained unsteady flow arising

from a disturbance set up by either the flight conditions or design of the airframe.

BUFFING. The smoothing of a metal surface by means of abrasive rotating wheels, commonly surfaced with a flexible material carrying the abrasive.

BULK DENSITY. An expression for the density of fuel-oxidizer combinations burned in rocket motors. It is of the form:

$$\rho = \frac{r + 1}{\frac{r}{\rho_0} + \frac{1}{\rho_f}}$$

where ρ is the bulk density, r is the mixture ratio, ρ_0 is the oxidizer density, and ρ_f is the fuel density. It is normally measured at some fixed temperature (sometimes 80°F). It is sometimes designated by the symbol d .

BULKHEAD. A partition or framing member mounted transversely to the longitudinal axis of an airframe, airplane, ship or other vehicles. It serves to separate one section from another and often gives shape to the external configuration.

BULL DOG. A U.S. Navy air-to-surface rocket missile under development by the Glenn L. Martin Company (Proposed).

BULL GOOSE (GOOSE). A USAF decoy missile program, under development by the Fairchild Engine and Airplane Corporation.

BULL PUP. (X-ASM-N-7.) The U.S. Navy air-to-surface missile produced by the Glenn L. Martin Company, having a canard configuration and using an Aerojet General solid-propellant rocket. Its dimensions are 11 ft long. Its weight is less than 600 pounds. (See **missile, guided.**) (See also illustration facing Page 59.)

BUMBLEBEE. A series of surface-to-air missiles sponsored by the U.S. Navy (Bureau of Ordnance) and developed by various contractors (Convair, Bendix) under the technical direction of the Applied Physics Laboratory of Johns Hopkins University. Terrier and Talos were of this family.

BUMPER. The code name of the high altitude rocket project involving a V-2/WAC-Corporal first and second stage combination. On 24 February 1949 at 1514 hours this com-

bination reached the then record altitude of 389 kilometers, achieving an end velocity of 5100 miles per hour. There were a total of 8 Bumper firings, all part of the Hermes Project. The last two firings, #7 and #8 were done at Cape Canaveral, Florida, that of Bumper #7 occurring on 24 July 1950. These flights were not for altitude but the V-2 was programmed to tilt horizontally at 10 miles altitude so that the WAC Corporal was in that position for its thrust period. Exact figures on the range attained are not disclosed, but it was probably on the order of 200 miles. The high altitude flights were made at White Sands Proving Ground, New Mexico. The V-2 burned for approximately 60 seconds attaining 3400 mph at burn-out, and the WAC Corporal burned for approximately 40 seconds more, adding its thrust to attain the 5100 mph end velocity.

BUMPER MISSILE. A two-stage rocket missile.

BuOrd. Department of the Navy, Bureau of Ordnance.

BUOYANCY. The apparent loss of weight by a solid body immersed wholly or partially in a fluid. The total buoyancy force is equal to the weight of the displaced fluid and acts through the position of the center of gravity of the displaced fluid.

BURBLE. A term describing the action of air over the upper surface of an **airfoil** when the **angle of attack** has been increased to the point where the air stream no longer follows the profile of the airfoil but breaks away from it. The space between the airfoil and the detached air stream is filled with eddying, burbling air, and the lift is largely lost. The airfoil is then said to have reached the burble point. This is synonymous with "stalled" in wing terminology. (See **stagnation point.**)

BURNER. (1) A combustion chamber, or can, in a jet engine. (2) A fuel-injection nozzle in the combustion chamber of a jet engine.

BURNER BASKET. An inner liner of a jet engine.

BURNER DRAG. Total drag due to the presence in a missile propulsive system of the combustion sub-system; usually including

the drag force on the igniter, flame holders, diffuser wall, combustion chamber wall, etc. The burner drag is more significant in an atmospheric jet engine than in a rocket-propelled missile, because the latter contains no center body diffuser, flame holders, injection system, turbines, etc. in the line of combustion flow—that is, the entire crosssection of the motor is enclosed within the missile body.

BURNER RING. In a turbojet engine, a ring consisting of the fuel manifold together with the fuel nozzles for each combustion chamber.

BURNING RATE. For solid propellant fuels, the rate of burning (“ r ”) is the linear measure (normal to the burning surface) of the propellant grain which is consumed in unit time, usually expressed in inches per second.

BURNING RATE, EROSIVE. The increase in burning rate over normal conditions, which is incident to the sweep of hot gases over a burning propellant surface.

BURNING RATE, LINEAR. The rate at which a solid propellant burns normal to its surface under design combustion chamber pressure. The burning rate is in accordance with Muraour’s relationship. It is given by the relationship:

$$r_0 = a_2 p_c^n = \frac{dw/dt}{A_p \gamma_p},$$

where r_0 is the linear burning rate, a_2 is an experimental constant, p_c is the chamber pressure, n is a variable exponent, dw/dt is the rate of flow of propellant by weight, A_p is the burning surface and γ_p is the specific weight of propellant.

BURNING, ROUGH. Severe pressure fluctuations frequently observed at the onset of burning, but which can occur at any time, and at the combustion limits of ramjet or rocket.

BURNISHING. The smoothing of a metal surface by means of a hard tool. Steel or agate are used. Ball burnishing is a technique in which an object is agitated in a container with small steel balls.

BURNOUT. (1) The termination of burning of a jet or rocket engine because of the exhaustion of fuel. The term should be distinguished from **cut-off** which implies a cessa-

tion of burning brought about by means other than exhaustion of fuel. (2) The rupture of a combustion chamber through excessive heating.

BURNOUT POINT. The point on the missile trajectory at which the fuel supply of a specified rocket engine (booster, sustainer, or vernier) is exhausted.

BURNOUT VELOCITY. The velocity of a rocket, rocket-powered aircraft, or rocket-powered projectile when fuel combustion terminates due to exhaustion.

BURNOUT WEIGHT. The weight of a missile at the time usable fuel supply is exhausted, but including any residual, unusable fuel.

BURST. (1) The explosion of a warhead. (2) Rupture of a solid propellant rocket case incident to excessive combustion pressure. (3) In cosmic ray measurements, an exceptionally large electric pulse observed in an ionization chamber, signifying the simultaneous arrival or emission of several or many ionizing particles. Such an event may be caused by a cosmic-ray shower or by a spallation disintegration of the type that can produce a star. (4) In communications, a sudden increase in signal strength of waves being received by ionospheric reflection. The effect is believed to be caused by a disturbance of the ionosphere by meteors.

BURST DIAPHRAGM. A thin diaphragm in a pneumatic or hydraulic system which ruptures at a predetermined fluid pressure in order to initiate a desired sequence of events, e.g., the ignition of a motor through the production of a hypergolic starting mixture, or the relief of pressure (or other safety function). Burst diaphragms may be used to prevent the flow of corrosive fluids into unprotected plumbing systems until they are operated. Also called a “burst disk” or a “rupture disk.”

BURST DISK. Burst diaphragm.

BUS. (1) In electrical devices, any rigid or heavy conductor used to distribute current to several branches. (2) The main power line of a missile power system. (3) In computers, one or more conductors which are used as a path for transmitting information from any

of several sources to any of several destinations.

BuShips. Department of the Navy, Bureau of Ships.

BUSWAY. A sheet metal trough or tube containing electrical conductors in the form of copper bars (or sometimes aluminum). It is a conduit for a **bus**.

BUTTERFLY VALVE. A fluid control device consisting of a circular disc mounted on a diametric axis inside a conducting tube or pipe. The valve is made to match the diameter of the inside of the tube and is closed by turning it on its axis.

BUTYL MERCAPTAN. An organic compound having the formula C_4H_9SH , which has been considered for use as a rocket fuel. The boiling point is 206-210°F, flash point, -162°F, and specific gravity, 0.835.

BuYdsDcks. Department of the Navy, Bureau of Yards and Docks.

BUYS BALLOT'S LAW. "Standing with back to wind, low pressure is to left and high pressure to right in northern hemisphere, with the reverse being true in the southern hemisphere." This law was one of the earliest statements of the principles of winds now accepted as common meteorological knowledge.

BUZZ. Diffuser buzz; dither.

BUZZ BOMB. The popular name for the German World War II V-1 missile. The name was derived from the characteristic sound of its pulse jet engine.

BV-143. German World War II guided air-to-surface subsonic missile. It weighed 2000 kilograms, was 6 meters long and used a hydrogen peroxide-permanganate rocket motor of 40 seconds burning time. It was essentially a steerable bomb.

BV-246. A German World War II guided missile of the air-to-surface type. It resembled a small monoplane aircraft with a horizontal stabilizer and two small vertical fins. It was made of metal and approximately 11 feet long. Wings for these missiles were made of concrete. Span was 21 feet tip-to-tip. Total weight of this glide bomb was 1,600 pounds. Guidance was radio command with tail flares for visual assistance.

BYPASS CAPACITOR. A capacitor used to provide a comparatively-low, shunting impedance for currents at some point in a circuit.

BY-PASS ENGINE. A gas-turbine reaction propulsion engine, incorporating an air bypass duct, to produce high thrust without excessive jet-stream velocities and give low specific fuel consumption.

C

C. (1) Capacitance or permittance or designation for capacitor (C). (2) Partial capacitance (c). (3) Third Cauchy constant (C). (4) Compliance (C). (5) Sound conductivity of an opening (c). (6) Concentration of solution (c or C). (7) Element carbon (C). (8) Velocity of light in vacuum (c). (9) Degree Centigrade (celsius preferred) ($^{\circ}\text{C}$). (10) Normality of solution (C). (11) Heat capacity, total (C), per unit mass (which is specific heat) (c), heat capacity per mole (c , C or C_M), heat capacity per atom or molecule (c or C_m), specific heat at constant volume (c_v), specific heat at constant pressure (c_p), molar heat at constant volume (C_v), molar heat at constant pressure (C_p). (12) Thermal conductance (C). (13) Chord length (aerodynamics) (c). (14) Exhaust velocity (c). (15) Specific fuel consumption (c). (16) Characteristic exhaust velocity (c^*).

C-2. The code designation for the German World War II AA missile *Wasserfall*.

C BAND. A radio frequency band of 3.9-612 kilomegacycles with wavelengths of 11.8 cm to 7.3 cm. It includes the top two side bands of $S_{(z)}$ through bottom three side bands of $X_{(x)}$.

C BATTERY. A battery used to supply bias.

Ca. Calcium.

CAA. Civil Aeronautics Administration.

CABANE. A structure consisting of a series of struts which carries the load from the wing to the fuselage of an airplane.

CABLE RACK. A shelf or hanger secured to the wall of a trench, tunnel, manhole, building, etc., to provide support for electrical cables.

CADASTRAL MAP. A map showing the boundaries of subdivisions of land, usually with the bearings and lengths thereof, and the areas of individual tracts for purposes of de-

scribing and recording ownership. A cadastral map may also show culture, drainage, and other features relating to the value and use of land.

CADDAC. A type of computer used as a missile safety indicating device.

CADMIUM. Metallic element. Symbol Cd. Atomic number 48.

CAF. Complete assembly for ferry.

CAGE. To lock the gyroscope of a gyro-controlled instrument in a fixed position with reference to its case.

CAL. Cornell Aeronautical Laboratory; Buffalo, New York.

CALCIUM. Metallic element. Symbol Ca. Atomic number 20.

CALIBER. (1) The outside diameter of a projectile. (2) In guns, the length in terms of the projectile diameter; or the minimum diameter of the gun tube. (3) In missiles, the maximum diameter of the central body section (not including fin or airfoil dimensions).

CALIBRATE. (1) To compare the readings of an instrument or meter with those of a standard in order to determine the necessary corrections. (2) To make adjustments to an instrument or meter so it will read correctly, except of course for observational errors.

CALIBRATED ALTITUDE. Altitude as determined by the application of corrections for static-pressure error, installation error, and instrument error to the indicated altitude shown by a pressure altimeter. (See indicated altitude.)

CALIBRATION CURVE. A graph showing the corrections to be applied to the readings of an instrument or meter.

CALIDO. A nickel-chrome electrical resistance wire.

CALIFORNIUM. Transuranic element. Symbol Cf. Atomic number 98.

CALLIOPE. Rocket, 3.5 inch.

CALORIE. A unit for the measurement of the quantity of heat. As originally defined, it was the amount of heat required to raise the temperature of one gram of water through one degree Centigrade. As thermal measurements increased in precision, this definition was not sufficiently exact and many different kinds of calories were used, considerable confusion resulting. After 1930 an artificial, conventional calorie was defined by the relation 1 calorie = 4.1833 international joules and, in 1948, it was redefined as 1 calorie = 4.1840 absolute joules. This definition is now generally accepted in the United States. The large calorie (Cal. or Kcal.) is 1,000 times as large. Another artificial calorie, used in engineering steam tables, is the International Table calorie: 1 I.T. calorie = $\frac{1}{860}$ international watt-hour = 0.00116298 absolute watt-hour.

Conversion to other energy units gives:

- 1 cal. = 0.00396573 B.T.U.
- 1 cal. = 0.0412917 liter-atmosphere
- 1 cal. = 0.999346 I.T. cal.

CALORIZING. The process of coating a metal with close-grained deposit of aluminum.

CAMBER. (1) The curved surface from the leading edge to the trailing edge of an airfoil as seen in cross section. The "upper chamber" refers to the upper curved surface, and the "lower chamber" to the lower surface. Camber is "positive" or "negative" when the curve is ascending or descending, respectively. (2) The ratio of the length of the upper curved surface of an airfoil (taken along the curve) to the length of a straight line between the two extremities of the curved surface. (3) The ratio of the maximum height from the chord of the airfoil to the length of the chord. (4) Camber is also the line equidistant from the upper and lower surfaces of an airfoil.

CAMBER LINE. The median line down the thickness of the profile of an airfoil; it is the locus of points half-way between the top and bottom of the upper and lower **camber** surfaces.

CAMERA. In guided missile development work, many types of cameras are used for

specific purposes in recording essential performance information. Cameras are used to obtain missile trajectory data; to record position, velocity, acceleration, and attitude information; to record range timing in coded light images or to maintain surveillance of critical operations (such as motor burning, take-off, control surface functioning, and separation of booster). For some data collection work, it is expedient to carry a camera inside the missile and rescue it after the flight by ejection and parachute descent. Cameras may be either *fixed* or *tracking*, and the cameras themselves may be *ballistic*, *motion picture*, *ribbon-frame*, or many other types.

CAMOUFLET. A subterranean cavity resulting from an underground explosion.

CAN COMBUSTOR. Combustor, can.

CANARD CONFIGURATION. A type of airframe in which the control surfaces are small and well forward of the body, while the main lifting surfaces are rigidly attached in the aft region of the body. Lift is obtained by increasing the angle of attack of the body-wing combination by means of the forward control surface. The advantage of the canard configuration is that the horizontal stabilizer is mounted at a greater angle of attack than the main wing and therefore stalls earlier. This results in better stall characteristics. The canard configuration fell into disuse for aircraft because power plants were mounted in the nose to provide the propeller with the least disturbed air for the development of thrust, so any further extension of the airframe in advance of the propeller was objectionable. With jet and rocket aircraft the canard configuration returned to use.

CANCER. (The crab.) Cancer is the name of a small and poorly marked **constellation** of faint stars that is of importance principally because it is the fourth sign of the **zodiac**. In this constellation is found the fine **cluster** known as Praesepe (or the Beehive). The stars are not so numerous as in some other star clusters, but are of sufficient brightness to make this an interesting object in a small telescope. Galileo counted 36 stars with his telescope but observers using modern equipment have counted over 300. On a clear moonless night the object appears as a faint glow of light, and is frequently used by as-

tronomers as a test of the transparency of the atmosphere.

CANDELA. Unit of **luminous intensity**: it is of such a value that the luminous intensity of a full radiator at the freezing point of platinum is 60 units of luminous intensity per cm^2 . (See also **candle**.)

CANDLE. Unit of **luminous intensity**. One candle is defined as the luminous intensity of $\frac{1}{60}$ square centimeter of a **blackbody** radiator operating at the temperature of solidification of platinum. Values for standards having other spectral distributions are derived by the use of accepted luminosity factors. One candle produces one lumen of luminous flux (see **flux**, **luminous**) through an area subtending a solid angle of one steradian measured from the source.

CANDLE POWER. In the earlier days of photometry, **luminous intensity** was measured by rating a source in terms of ordinary candles. The need for greater precision and reproducibility led to, first, specification of the materials and dimensions of the candle or lamp, and more recently to the definition of the standard candle in terms of the luminous intensity of a blackbody radiator at the temperature of solidification of platinum. (See **candle**.)

CANIS MAJOR. (The great dog.) Both this **constellation** and its companion Canis Minor, or the little dog, have been named from remote antiquity as the dogs of **Orion**. Sirius in Canis Major and Procyon in Canis Minor are both well-known stars, Sirius being the brightest observable. Sirius is not only the brightest, but also the closest star visible to the naked eye which can be observed in the **latitudes** of Europe or North America. Intrinsically Sirius has a brightness more than 20 times that of our sun. Both Sirius and Procyon have faint companions, that of Sirius being particularly famous as the first of the **white dwarfs** discovered.

CANISTER. A protective container for housing or storing a missile system, subsystem, or component, usually a pressurized cylindrical can.

CANNIBALIZATION. A maintenance, modification or repair method in which the required parts are removed from a similar missile

or assembly for installation on another. Sometimes used in lieu of formal spare parts provisioning.

CANT ANGLE. The angle between the nozzles and main thrust line, e.g., angle of cant of a spin-stabilized rocket. Nozzle cant angles are usually limited to a maximum value of 30° , and typically are 15° because of impulse loss and local heating.

CANTED. Tilted; e.g., a rifle having its plane of symmetry out of vertical; a radar beam that is displaced through some vertical angle measured at right angles to its direction of propagation; a nozzle whose thrust axis makes an angle with the axis of symmetry of the missile it propels.

CANTILEVER. Supported at one end, e.g., a cantilever beam is rigidly connected at one end to a fixed support and free to move at the other end. Airfoil surfaces are said to be cantilever-constructed when they have no external bracing.

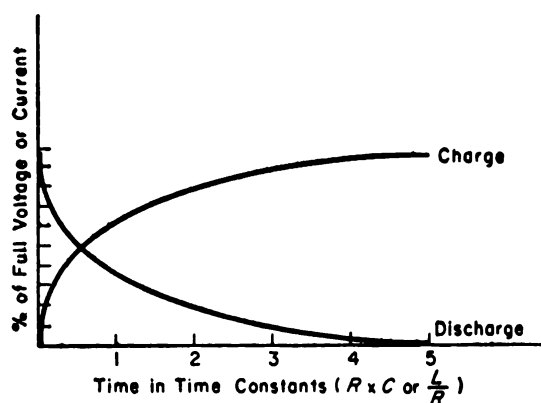
CAPABILITY. The ability of a nation or an operating force to carry out a certain type of strategic warfare or a certain tactic, e.g., "atomic warfare capability."

CAPACITANCE. (1) Ratio of the **electric charge** given a body to the resultant change of **potential**. It is usually expressed in **coulombs** of charge per volt of potential change, that is, in terms of the farad, or its submultiples; the c.g.s. electromagnetic unit is the abfarad. If a conductor is completely isolated, that is, far removed from other conductors, including the earth, and is surrounded by a homogeneous, perfectly insulating dielectric, its capacitance depends only upon the size and shape of its external surface, and upon the **dielectric constant** of the surrounding medium. Mathematically the electrical capacitance of a system is that coefficient which, when multiplied by 2π times the frequency is the reciprocal of the negative imaginary part of the electrical impedance. (2) In an acoustical system, that coefficient which, when multiplied by 2π times the frequency, is the reciprocal negative imaginary part of the acoustical impedance. The unit is centimeters to the fifth power per dyne.

CAPACITANCE ALTIMETER. Altimeter, capacitance.

CAPACITANCE, DISTRIBUTED. The capacitance which is inherent in any coil because of the adjacent turns, layers, windings, etc., which are separated by some dielectric material and which have voltage differences between them. The result of this is a capacitance action which lowers the effective inductance of the coil. This capacitance is often considered as lumped and in parallel with the true inductance of the coil (or other arrangement of conductors).

CAPACITOR (ELECTRICAL). An arrangement of conductors and dielectrics used to secure an appreciable capacitance, sometimes one of specified value. The essential feature of all capacitors is a system of two or more conductors, separated by layers of dielectric. Many modern capacitors consist of alternate metal and dielectric plates or sheets, sometimes of metal foil and paraffin paper strips rolled in a compact bundle. Capacitors in which the dielectric is air, usually of adjustable capacitance, are much used in radio and other oscillatory circuits. An electrolytic capacitor consists of an electrolytic cell in which a current has deposited a very thin layer of nonconducting material on one of the electrodes. The manner in which a capacitor charges or discharges through an impedance is illustrated in the figure.



Capacitor charging.

CAPACITOR, BY-PASS. A capacitor placed in an electrical circuit to allow a-c to flow around some circuit component and cause d-c to flow through the component. The most common usage is in by-passing various voltage-dropping resistors used in vacuum-tube circuits to adjust the voltages applied to the several parts of the circuits. These resistors

are by-passed so there will be no, or very little, alternating signal voltage drop to produce undesirable feedback. The reactance of the capacitor should be low compared to the resistance of the resistor being by-passed.

CAPACITOR, COUPLING OR BLOCKING. A capacitor incorporated in an electronic circuit to separate a-c and d-c components, and to isolate various parts of the d-c circuit while maintaining effective a-c connections.

CAPACITOR FORMULAS. (1) The capacitance of n capacitors connected in parallel is

$$C = \sum_1^n C_i$$

(2) The capacitance of n capacitors connected in series is

$$\frac{1}{C} = \sum_1^n \frac{1}{C_i}$$

CAPACITOR TRIMMER. A small capacitor used to adjust a tuned circuit to the desired resonance frequency. Essential in tracking superheterodyne receivers.

CAPE CANAVERAL. A cape on the east coast of Florida, the site of Cape Canaveral Auxiliary Air Force Base, used as a laboratory for launching missiles or space vehicles.

CAPILLARITY. The phenomena which are caused by surface tension and occur in fine bore tubes or channels. An example is the elevation (or depression) of liquid in a capillary tube partially immersed.

CAPILLARY. A cylindrical space of small radius, or a tube containing such a space.

CAPRICORNUS. (The sea-goat.) This is a constellation of small stars, not at all striking in appearance, but important because it is the tenth of the zodiac. The star Alpha (named Giedi) is one of the more remarkable stars, it being actually made up of six components. The two larger can be seen by some keen-eyed persons as separate, but it is easily resolved by means of an opera glass. Each of these two components may be still further resolved into three component parts with appropriate telescopes.

CAPSTAN. A vertical cylinder revolving on a vertical axis used for moving objects by the

traction of a rope passing several times around the cylinder. These devices are frequently found on shipboard, and in missiles are sometimes part of the control systems in which mechanical linkages are used.

CAPTIVE FIRING. Captive (Ground) Test.

CAPTIVE FLIGHT. (1) A flight wherein a guided missile, or component thereof, is carried on an aircraft in order to test the item under flight conditions. (2) A test, usually on the ground, in which the test article has some freedom for functioning but with restraints that permit reuse of the missile.

CAPTIVE (GROUND) TEST. A technique of operating a missile on a test stand to determine or check its performance. Engines can be operated to full thrust and all conditions except those caused by actual flight can be simulated. Also termed static test.

CAPTURE. (1) A process in which an atomic nucleus acquires an additional particle. (2) The process in which a missile, having achieved flight speed, is taken under control by the guidance system.

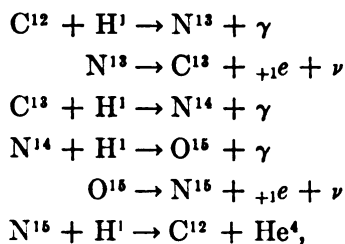
CAPTURE EFFECT. An effect in FM reception where the stronger signal of two stations on the same frequency completely suppresses the weaker signal.

CAPTURE MANEUVER. Maneuver, capture.

CARBIDE. A binary compound of carbon. Certain carbides, e.g., those of tungsten, silicon, titanium and tantalum, are widely used as abrasives.

CARBON. Non-metallic element. Symbol C. Atomic number 6.

CARBON CYCLE. A series of thermonuclear reactions, releasing great quantities of energy (by conversion from mass and by radiation) which are believed to furnish the energy radiated by many of the stars. This scheme was developed from theoretical considerations by H. A. Bethe in 1939 (and simultaneously by C. F. von Weizsäcker). Various possibilities were tried, but the following series was the only one which gave results in agreement with the experimental facts:



where ${}_{+1}e$ indicates a positron and ν indicates a neutrino. (See proton-proton chain.)

The overall reaction results in the production of a helium atom, two positrons and much energy, from four protons, the carbon atom that reacted initially being regenerated at the end of the process. There are, of course, other probable side-reactions.

CARBON DIOXIDE. A colorless gas of formula CO_2 and density 1.9769 grams per liter. It is a product of combustion of organic materials as well as animal respiration.

CARBURETION. The vaporization of fuel and mixing of it with air to form a combustible mixture for an internal combustion engine.

CARBURIZING. A process in metallurgy applied to develop a hard surface on metals. There are two widely-used carburizing treatments, the first being used to develop a hard surface, and the second to give a hard surface and a tough core as well. The first procedure consists of heating the parts to be carburized in lampblack, cyanides, or other sources of carbon to a temperature of 1650-1700°F., quenching them in water, and drawing them to the required hardness. The second method is essentially the same, except that after the quench the parts are reheated to 1400-1450°F., re-quenched and then drawn.

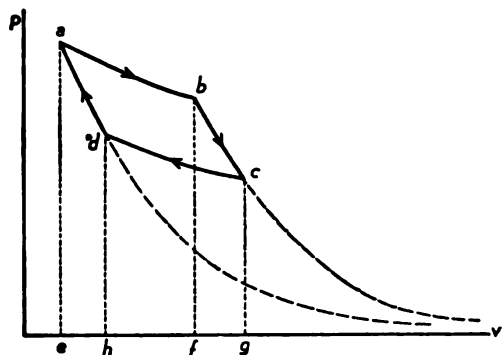
CARCINOTRON. A backward-wave oscillator tube capable of operation in a wide band of frequencies and therefore of interest in electronic countermeasures.

CARDAN MOUNTING. A gimbal-mounting system for a device requiring freedom of movement in one, two or three degrees. It is also called a universal suspension when providing three degrees of freedom.

CARDINAL DIRECTIONS. The four principal directions, north, south, east and west.

CARDINAL POINTS OF A LENS SYSTEM. The focal points, the principal points and the nodal points.

CARNOT CYCLE. An ideal cycle of four reversible changes in the physical condition of a substance; useful in thermodynamic theory. Starting with specified values of the variable temperature, specific volume, and pressure, the substance undergoes in succession (1) an isothermal (constant temperature) expansion, (2) an adiabatic expansion (see **adiabatic processes**), and (3) an isothermal compression to such a point that (4) a further adiabatic compression will return the substance to its original condition. These changes are represented on the volume-pressure diagram respectively by ab , bc , cd , and da in the accompanying figure. Or the cycle may be reversed: $a d c b a$.



Carnot cycle on V-P diagram; ab and cd , isothermals, bc and da , adiabatics.

In the former (clockwise) case, heat is taken in from a hot source and work is done by the hot substance during the high-temperature expansion ab ; also additional work is done at the expense of the thermal energy of the substance during the further expansion bc . Then a less amount of work is done on the cooled substance, and a less amount of heat discharged to the cool surroundings, during the low-temperature compression cd ; and finally, by the further application of work during the compression da , the substance is raised to its original high temperature. The net result of all this is that a quantity of heat has been taken from a hot source and a portion of it imparted to something colder (a "sink"), while the balance is transformed into mechanical work represented by the area $abcd$. If the cycle takes place in the counter-clockwise direction, heat is transferred from the colder to the warmer surroundings at the expense of the net amount of energy which must be supplied during the process (also represented by area $abcd$).

CARRIER. An electrical wave, usually sinusoidal in form, which may be modulated and transmitted in order to convey information from one place to another. Carrier waves are usually generated at radio frequencies in order to take advantage of electromagnetic radiation in transmitting the information. Modulation of the carrier may be of several types, e.g. amplitude, frequency, pulse, etc. (See **modulation**.)

CARRIER, CONTROLLED (VARIABLE OR FLOATING). A system of compound modulation wherein the carrier is amplitude-modulated by the signal frequencies in any conventional manner, but, in addition, the carrier is also amplitude-modulated in accordance with the envelope of the signal, so that the percentage of modulation, or **modulation factor**, remains relatively constant regardless of the amplitude of the signal.

CARRIER CURRENT. A relatively high-frequency a-c superimposed on the ordinary circuit frequencies in order to increase the usefulness of a given transmission line. In the case of power systems, carrier currents of several kilocycles frequency are coupled to the 60-cycle transmission lines. These carrier currents may be **modulated** to provide telephone communication between points on the power system, or they may be used to actuate **relays** on the system. This latter use is known as carrier relaying. Carrier currents have greatly extended the usefulness of existing line facilities of the telephone and telegraph companies. Several carrier frequencies may be coupled to the lines already having regular voice or telegraph signals on them. Each of these carrier frequencies may be modulated with a separate voice or telegraph channel, and thus a given line may carry the regular signals plus several new carrier channels, each of which is equivalent to another circuit at regular frequencies. At the receiving end the various channels are separated by **filters**, and the signals demodulated, and then fed to conventional phone or telegraph circuits.

CARRIER FREQUENCY. In a periodic carrier, the reciprocal of its period. The frequency of a periodic pulse carrier often is called the pulse-repetition frequency (prf).

CARRIER-FREQUENCY RANGE OF A TRANSMITTER. The continuous range of

frequencies within which the transmitter may be adjusted for normal operation. A transmitter may have more than one carrier-frequency range.

CARRIER-FREQUENCY STABILITY OF A TRANSMITTER. A measure of the ability of the transmitter to maintain an assigned average frequency.

CARRIER ROCKET. A rocket whose primary function is transport, as the carrier rocket of an artificial satellite.

"CARRIER SHIFT" (ASYMMETRICAL MODULATION). The production of unequal amplitudes of positive and negative modulation peaks due to nonlinearities in the modulated stage. This effect may be regarded as a shift in carrier amplitude or power, and not as a shift in carrier frequency.

CARRIER SUPPRESSION. That method of operation in which the carrier wave is not transmitted.

CARRIER-TO-NOISE RATIO. The ratio of the value of the carrier to that of the noise after selection and before any nonlinear process such as amplitude limiting and detection.

CARRY. (1) A condition occurring in addition when the sum of two digits in the same column equals or exceeds the base of the number system in use. (2) The digit to be forwarded to the next column. (3) The action of forwarding it.

CARRY-AROUND OXYGEN BOTTLE. A metal bottle containing oxygen that may be carried by personnel. Sometimes called a "carry-around oxygen cylinder," also a "walk-around oxygen bottle."

CARTESIAN CONTROL. A special kind of guided-missile control dependent upon two sets of control surfaces, each producing movement perpendicular to that produced by the other.

CAS. Complete assembly for strike.

CASCADE. A connected arrangement of separative elements whose function is to multiply an effect. An example in electronics is a group of similar components arranged consecutively in series so that an electrical property is additive.

CASCADE CONTROL. An automatic control system in which the control units, linked in chain fashion, feed into one another in succession, each regulating the operation of the next in line. (Sometimes termed "piggy-back" control.)

CASE-BONDED GRAIN. Grain, case-bonded.

CASE HARDEN. To produce a hard surface layer on steel or other ferrous material by a heating process in a carbonaceous medium; often followed by quenching. (See **Carburizing**.)

CASF. Composite air strike force.

CASSEGRAINIAN MIRROR. The secondary mirror in a **Cassegrainian telescope**.

CASSEGRAINIAN TELESCOPE. A reflecting telescope in which a secondary convex mirror reflects the light from the collecting mirror back through a hole in its center. The first real image is commonly formed just behind the collecting mirror.

CASSIOPEIA. One of the most widely known and striking constellations of the northern latitudes. It is easily recognized by the 5 bright stars forming an irregular W, some observers seeing not only a W but also a chair. Since this object is circumpolar (i.e., remains above the horizon at all hours every night) for most northern countries, and is easily recognized, it is frequently used as a rough indicator of sidereal time. The leading bright star of the W (the star Beta Cassiopeiae) lies almost in zero hours right ascension. Hence a line drawn through Polaris and Beta Cassiopeiae must pass close to the vernal equinox. The hour angle of this line must be equal to sidereal time. Hence when Beta Cassiopeiae is on the meridian directly above the pole the sidereal time is zero, when on the meridian directly below the pole the sidereal time is 12 hours, etc.

CAST IRON. An iron-carbon alloy, whose characteristic properties result from the occurrence of much of the carbon in the form of graphite, incident to the method of formation of the alloy, and the presence of silicon. Other alloying elements may also be present.

CASUALTY. (1) An individual who is unable to discharge his primary duties. An indi-

vidual who can be cared for by the unit medical support and returned to duty is not considered a casualty. (2) An event of adverse consequences (e.g., premature explosion).

CAT. A name compounded from the initial letters of the words Celestial Atomic Trajectory, a proposed anti-satellite missile to be used to attack the Minimum Orbital Unmanned Satellite, Earth (i.e., MOUSE).

CATALYSIS. A phenomenon observed in chemical reactions whereby the reaction between two or more substances is influenced by the presence of a third substance (the catalyst) which remains apparently unchanged in the process.

CATALYST. Catalysis.

CATAPULT. A fixed structure which accelerates a missile or aircraft. It must combine the function of directing and accelerating the missile during its travel on the catapult; thus it serves the same function for a missile as does a gun tube for a shell. Catapults derive their propulsive forces from the use of explosives, steam, compressed air or other power. (See **launcher**.)

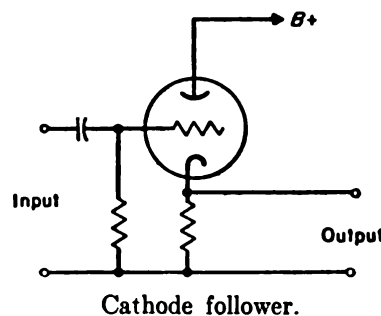
CATHEDRAL. In aerodynamic design, the opposite of dihedral. It is the angle of downward slope of an airfoil surface when viewed from the front. Wings which appear to "droop" downward have cathedral.

CATHODE. (1) In general, the electrode at which positive current leaves a device which employs electrical conduction other than that through solids. (2) In an **electron tube**, the electrode through which a primary stream of electrons enters the interelectrode space. (3) The negative terminal of an electroplating cell (i.e., the electrode from which electrons enter the cell, and thus at which positively charged ions (cations) are discharged). (4) The positive terminal of a **battery**.

CATHODE, COLD. (1) A cathode in an **electron tube** or a **gas discharge tube** that functions without the application of heat. (2) A specific type of cold cathode is an electrode furnishing electrons by secondary emission, sometimes used as a source of ions.

CATHODE FOLLOWER. A circuit in which the output load is connected in the

cathode circuit of an electron tube, and the input is applied between the control grid and the remote end of the cathode load. The circuit is characterized by low output impedance, high input impedance, gain less than unity under most operating conditions, and an output voltage nearly independent of the current taken from the output terminals. (See figure.)

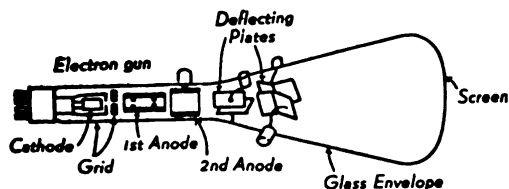


CATHODE RAY(S) (CATHODE STREAM). Originally, this term applied generally to a stream of electrons emitted from the cathode of a gas discharge tube, during its bombardment by positive ions. The term has been extended to denote any stream of electrons, such as those emitted by a heated filament. The emitted electrons are capable of causing **phosphorescence**, chemical changes, mechanical effects; they can raise the temperature of bodies which are subjected to their bombardment, penetrate solids, and give rise to **x-rays**.

CATHODE-RAY OSCILLOSCOPE. See **cathode-ray tube operated as oscilloscope**; also **cathode-ray tube**.

CATHODE-RAY TUBE. A special form of vacuum tube used in various electronic applications, e.g., as the picture tube of the television receiver and as an oscilloscope tube. The tube consists fundamentally of three sections enclosed in an evacuated bulb. The first is the electron gun which produces and projects down the tube a beam of electrons. This gun has a **cathode**, usually indirectly heated, which emits a plentiful supply of electrons, then a **grid** which controls the number of electrons drawn towards the anode and finally the **anode**. Both the grid and anode are different in structure from the corresponding elements of the conventional vacuum tube. They consist of metal cylinders, coaxial with the cathode and closed at the end except for a small circular hole. Many of the electrons

which are drawn towards the anode under the influence of the grid and anode voltages pass through these holes and are projected as a beam into the main part of the tube. Here they are focused upon the screen by electric or magnetic fields in a manner analogous to the focusing of light rays by a lens system. In passing down the tube the beam passes between two sets of plates, called deflecting plates, which are perpendicular to one another. A voltage applied to either of these sets will deflect the beam towards the positive plate. Sometimes the plates are omitted and coils outside the tube substituted. A current through the coils will set up a magnetic field and hence cause deflection of the beam.



Finally the beam hits the screen which is a coating on the end of the tube of some material which will fluoresce under the impact of the electrons. Reference to the figure will show the relative positions of the various parts of the tube. (See also **kinescope**.)

CATHODE-RAY TUBE (OPERATED AS OSCILLOSCOPE OR TELEVISION PICTURE TUBE). The **oscilloscope** is used primarily for studying the current or voltage wave forms present in a circuit which is being investigated. If the voltage being studied is connected to one set of the deflecting plates it will cause the electron beam in the tube to move back and forth as the voltage varies. This will cause the fluorescent spot on the screen to move, and due to the persistence of the screen it will appear as a line. If now, another voltage is placed on the other set of plates it will move the beam and hence the screen spot, the resultant being a line pattern which is a combination of the effects of both voltages. Usually the second voltage is a sawtooth wave which gives linear (with respect to time) deflection of the spot and hence the pattern will be the same as if the first wave were plotted on conventional rectangular coordinates. For current study either the voltage drop, caused by the current through a resistor, is used or the current is passed

through the coils of the magnetic deflection type. For use as a television picture tube the picture signals are applied to the various electrodes so the fluorescence of the screen is a reproduction of the original scene being televised.

CATION. A positively charged ion.

CAVITATION. The formation of local cavities in a fluid as a result of the reduction of total pressure. For non-degassed liquids, these cavities are filled with the gases dissolved in the liquid and are produced whenever the instantaneous pressure falls below the vapor pressure. This effect is sometimes called pseudo-cavitation, to distinguish it from the effect in pure degassed liquids, where an actual rupture of the medium occurs (at much higher sound pressures). Collapse of such cavities produces very large impulsive pressures that may cause considerable mechanical damage to neighboring solid surfaces. Cavitation is synonymous to turbulence in aerodynamic flow.

CAVITY RESONATOR. A space normally bounded by an electrically conducting surface in which oscillating electromagnetic energy is stored, and whose resonance frequency is determined by the geometry of the enclosure. Cavity resonators are used as sources of microwave oscillations. The cavity may be a length of waveguide closed at each end, so arranged as to have an input excitation by means of a coupling loop or probe. If the dimensions of the section are suitably chosen, the waves reflected from the ends interact to produce standing waves, and the cavity resonates. Maximum current flows along the side walls of a resonant cavity. Oscillation may take place in modes corresponding to the "H" or "E" waves in wave-guides, and either of these two types can occur in a number of modes, each of which corresponds to a different frequency. The efficiency of resonant cavities as compared to ordinary **tank circuits** is very high.

CCAFB. Cape Canaveral Auxiliary Air Force Base; Cape Canaveral, Florida.

Cd. Cadmium.

C_D . Coefficient of drag.

C_{Di} . Coefficient of induced drag.

C_{Do}. Coefficient of profile drag.

C_{DP}. Coefficient of parasitic drag.

Ce. Cerium.

CEA. Circular Error Average.

CEILING. (1) The maximum height to which an airplane or missile can rise (absolute ceiling). (2) A capability of any given airplane or airborne missile measured by its absolute ceiling. (3) The maximum height at which an aircrew or passengers can fly, either with or without special equipment. (4) An overcast of clouds above a given area limiting vertical visibility, sometimes defined more rigorously as the lowest cloud layer that, in summation with all lower layers of clouds and obscuring phenomena, covers 60 per cent or more of the sky. (5) The height of the lower surface of such an overcast.

CELESTIAL ALTITUDE. The vertical angle between an observer's celestial horizon and a line joining a celestial body with the earth's center.

CELESTIAL AXIS. The axis around which the **celestial sphere** apparently rotates by reason of the earth's rotation. The celestial axis is coincident with the earth's axis.

CELESTIAL BODY. (1) A material body that exists in the heavens. (2) Any such body exclusive of a manmade space vehicle.

CELESTIAL COORDINATE. One or other of two coordinates on the surface of the **celestial sphere** used to locate a celestial body. The commonly used coordinates are **right ascension** and **declination**.

CELESTIAL EQUATOR. The great circle of the **celestial sphere** formed by extending the plane of the earth's equator until it cuts the celestial sphere. It is also known as the "equinoctial equator."

CELESTIAL FIX. A **fix** or position obtained through observation and altitude measurements of celestial bodies.

CELESTIAL GUIDANCE. The guidance of a missile by means of instruments and devices which automatically sight preselected celestial bodies, calculate positions, and direct the missile along a predetermined flight path.

CELESTIAL HORIZON. A great circle on the celestial sphere, established by a plane passing through the center of the earth, perpendicular to the zenith-nadir axis of an observer, and intersecting the celestial sphere; also, the plane that establishes this great circle.

CELESTIAL INTERCEPT. In celestial navigation, an imaginary line extending from an assumed position to intercept a **line of position** and used to compute the altitude of a given celestial body; the distance and direction of a line of position from an assumed position.

CELESTIAL MECHANICS. The field of astronomical study and research which deals with the motions of two or more bodies in space under the influence of their mutual gravitational attractions. The fundamental elements of the subject are found in the Newtonian law of universal gravitation (see **Newton theory of gravitation**), the laws of motion, and the Keplerian laws of planetary motion (see **laws of Kepler**). In the classical theory space of three dimensions is treated, with time considered as an independent variable. Within recent years some slight modifications of the classical theory, particularly when the time interval is very long or velocities and accelerations are very high, have become necessary on account of the theory of **relativity**. Under the general heading of celestial mechanics such problems are discussed as the development of the various methods for orbit computation, methods for computing perturbations, and solutions of the problem of three bodies.

CELESTIAL MERIDIAN. Any great circle on the **celestial sphere** that passes through its poles, especially either half of such a circle between the celestial poles.

CELESTIAL NAVIGATION. A means of navigation by which a geographical location is determined by reference to celestial bodies.

CELESTIAL NAVIGATION GUIDANCE. The automatic directing of **guided missiles** through the employment of **celestial navigation**. The missile is equipped with gyroscopes, telescopes, mechanically or electrically recorded navigational tables, and other instruments and devices that sight stars, calculate positions, and direct the missile.

CELESTIAL RADIO TRACKING. A navigation technique wherein the microwave emanations of the sun, moon or certain stars are used to ascertain their positions with reference to the point of observation.

CELESTIAL SPHERE. An imaginary sphere of infinite radius upon which the celestial bodies are assumed to be fixed. The celestial sphere is used as a convenience in solving problems in **celestial mechanics**, **navigation**, and related fields. Points on the celestial sphere are determined by their celestial **altitude** and celestial **azimuth**. Since the celestial sphere is infinite in size, the earth's radius is not significant in comparison, and calculations are based upon the assumption that terrestrial observations are made from the center of the earth rather than the surface.

CELESTIAL TRIANGLE. An **astronomical triangle** on the surface of the **celestial sphere**, whose vertices are the zenith, an elevated pole, and a celestial body.

CELSIUS. Centigrade.

CEMENTITE. The iron carbide (Fe_3C) constituent of steel and cast iron. It is very hard and brittle.

CENTAUR. A rocket under development capable of putting a 7400-pound satellite into a 300-mile orbit, or capable of a lunar mission. It is based on an Atlas first stage, and a specially designed second stage that burns hydrogen gas. Its third stage is based on a rocket carrying a storable fuel, capable of delayed ignition.

CENTAURUS. (The centaur.) This is a large and brilliant **constellation** of the southern sky, being invisible to observers in North America or Europe. Centaurus has two bright stars which are frequently spoken of as the "southern pointers" since the line through them passes through the southern cross (the constellation Crux). The brighter one of these two (Alpha Centauri) is not only the third brightest star in the entire sky, but is also the nearest bright star. The distance of this star is 4.3 **light years**, the only star thought to be closer than this to the earth being a faint star known as Proxima Centauri.

CENTER, ELASTIC. A point within the wing section at which the application of a single concentrated load will cause the wing to deflect without rotation and, conversely, a point within the wing section about which rotation occurs when the wing is subjected to pure torque.

CENTER FREQUENCY. See **carrier frequency**. Center frequency is commonly used only for aural transmitters.

CENTER OF ATTRACTION. The center of a **central force field**. It is also the center of an infinite number of equipotential spherical surfaces in space.

CENTER OF BUOYANCY. The point through which the resultant of the **buoyancy** forces on a submerged body act. It is coincident with the **center of gravity** of the displaced fluid.

CENTER OF DISPLACEMENT. The **center of gravity** of the fluid displaced by a floating body.

CENTER OF GRAVITY. (1) For an extended body of collection of particles subject to the earth's gravitation, the point through which the resultant force of gravity acts (i.e., the weight of the body or collection) no matter how the body is oriented. In a uniform gravitational field in which the ratio of gravitational force to mass is always the same, the center of gravity is the same as the center of mass. (2) In aerodynamics, a reference point at which static mechanical balance of the configuration occurs. Lift, drag, moments and other forces are considered to operate on this point or about it. The location of the center of gravity with respect to the center of aerodynamic pressure is an important consideration in the stability of missiles in flight. For stability the center of gravity (CG) should be in front of the **center of pressure** (CP).

CENTER OF MASS. The point at which all the mass of a body may be regarded as being concentrated, insofar as motion of translation is concerned. (Cf. **center of gravity**.)

CENTER OF PERCUSSION. In a rotating body, the point on a line passing through the center of rotation and the center of gravity at which force can be applied at a right angle

to this line without causing a reaction at the center of rotation. The location of the center of percussion is expressed as the square of the **radius of gyration** divided by the distance between the center of gravity and the center of rotation.

CENTER OF PRESSURE. (1) A hypothetical point on the longitudinal axis of a configuration, through which a single force would be equivalent to the combined effect of all the aerodynamic forces acting through the **center of gravity**. (2) For **airfoils**, the point where the line of action of the resultant force intersects the **chord line**. The center of pressure travels along a chord line as the airfoil is varied in **angle of attack**, and therefore the stability of the airfoil is dependent upon the manner of this travel. For a subsonic cambered airfoil, the center of pressure is on the chord, and throughout most of the flight range the center of pressure moves forward as the angle of attack increases and backward as the angle decreases. At low angles of attack the center of pressure may move off the trailing edge and disappear because there is no lift. For an uncambered airfoil (i.e., a symmetrical airfoil such as a flat plate), the center of pressure moves backward as the angle of attack increases and forward as the angle decreases. This type of movement produces a stable airfoil. Other aerodynamic considerations are often more important than stability in an airfoil, so many "unstable" airfoils are flown. For a cylindrical body the center of pressure should be to the rear of center of gravity for a stable configuration. (3) In the case of the body of a missile, the center of pressure moves with the angle of attack of the body and also with the speed of the body. A stable missile with the center of gravity forward of the center of pressure tends to become less stable with increasing **Mach number** for the center of pressure moves forward toward the center of gravity with increasing speed, and the center of gravity may also shift as the fuel is consumed.

CENTER OF PRESSURE COEFFICIENT. In aerodynamics, the ratio of the distance of the center of pressure from the leading edge of an airfoil to the chord length. If x is the distance from the leading edge of the airfoil back to the center of pressure, then center of pressure coefficient = x/chord .

CENTER OF THRUST. In propulsion, the axis along which the propulsion system delivers its force. It is the line of action of the propelling force, and is commonly referred to as the "thrust line."

CENTI. Prefix meaning one hundredth part ($\frac{1}{100}$ or 0.01).

CENTIGRADE. Temperature scales.

CENTIMETER. In the cgs system, 100th of a meter. It is 0.3937 inches, (i.e. 2.54 cm = 1 in). (See **units and dimensions**.)

CENTIPOISE. A standard unit of **viscosity**, equal to 0.01 **poise**, the c.g.s. unit of viscosity. Water at 20°C has a viscosity of nearly 1 centipoise.

CENTISTOKE. A unit of kinematic **viscosity**, specifically the kinematic viscosity of water at 20°C.

CENTRAL BODY. A body which produces a **central force field**.

CENTRAL CONTROL. (1) Control exercised over an extensive and complicated system from a single center. (2) The place from which this control is exercised.

CENTRAL FORCE FIELD. A gravitational field which is produced by a perfectly homogeneous and perfectly spherical body. Central force field theory is of particular importance in astronautics, because it is usually adequate for performance analysis and, often, for determining the basic flight path. In a central force field, all orbits are defined as conics, i.e., ellipses, parabolas or hyperbolas. Special cases of these orbits are radial motion (i.e., free fall or vertical ascent) and the **circular orbit**.

CENTRAL FORCE THEORY. A basis for assumptions used in computing the flight of projectiles above the atmosphere when the altitude-time function is not known for the entire trajectory. (See **central force field**.)

CENTRIFUGAL COMPRESSOR. A **compressor** in which the centrifugal forces resulting from rotational velocity imparted to the working fluid are used to convert the resulting kinetic energy into pressure. The typical centrifugal compressor consists of an impeller

rotating in a stationary casing. The working fluid enters the impeller axially, flows outward through channels formed by the impeller blades, and is thrown off the impeller with high velocity through one or more tangential ducts. (See **axial compressor**.)

CENTRIFUGAL FORCE. A radially outward force experienced by an observer in a reference frame which is rotating at an **angular velocity** ω with respect to an **inertial frame** (cf. **Coriolis effects** (2)). The centrifugal force is the reaction to the **centripetal force** necessary to hold the observer at a fixed point in the rotating frame, and thus has a magnitude equal to and a direction opposite to the centripetal force.

CENTRIFUGE. (1) An apparatus for the separation of substances by the application of centrifugal force incident to whirling motion. (2) Similarly, an apparatus to subject an equipment to a specified acceleration for test purposes.

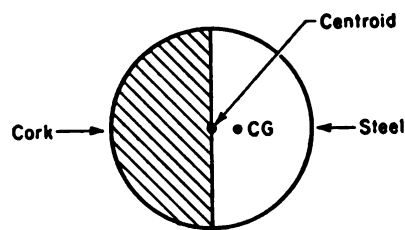
CENTRIPETAL. Moving inward, or directed inward, in the sense of toward a center.

CENTRIPETAL ACCELERATION. (1) The acceleration towards the center to which any particle moving in a circular orbit is subject. This acceleration is equal to v^2/r , where v is the orbital velocity and r the radius. (2) More generally, that part of the radial component of the acceleration of a particle moving in any curved path which is equal to the magnitude of the radius vector from the instantaneous center of rotation multiplied by the square of the instantaneous angular velocity about that center. (See **Coriolis effects**.)

CENTRIPETAL FORCE. The force necessary to impart **centripetal acceleration** to a body. For a body of mass m moving about a fixed axis at a distance r and with an angular velocity ω , the centripetal force is $-m\omega^2 r = -mv^2/r$, where v is the linear velocity of the particle and where the negative sign indicates that the force is directed radially inward. Effects such as the rupture of a rotating body or the outward skidding of an automobile in rounding a corner are often discussed as effects of centrifugal force, but are better described as being due to the insufficiency of the centripetal forces (elastic stresses or the frictional force of the wheels on the road) to maintain

the masses at constant distance from the center of rotation.

CENTROID. The centroid of a given geometrical figure (curve arc, portion of a plane or curved surface, or solid) is the point whose **coordinates** are the **mean values** of the coordinates of the points of the given figure; it is independent of the choice of axes. The centroid of a geometrical figure corresponds to the center of gravity (or center of mass) of a material body of the same shape and density distribution, but not otherwise except by chance. (See figure.)

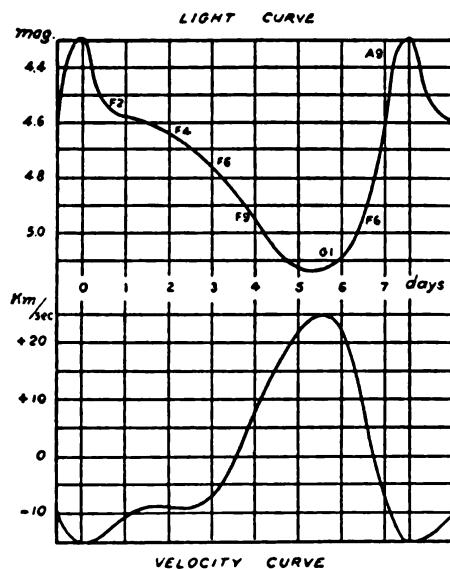


Distinction between centroid and center of gravity.

CEP. **Circular error, probable.** Sometimes written CPE.

CEPHEID. Examination of the curve in the article on **variable stars**, showing the number of variable stars of different periods, indicates that there are two groups of periodic variables with periods less than 50 days. The term Cepheid, derived from the typical short period variable δ Cephei, is applied to all variables with periods under 50 days. The group with periods less than one day are frequently referred to as cluster-type variables, because of the fact that they are most numerous in globular star clusters, while for purposes of differentiation Cepheids with periods greater than 1 day are referred to as "typical Cepheids." Since the classification of stars into type I and II populations (see **Giant and Dwarf Stars**), two corresponding kinds of typical cepheids are recognized.

The mean **light curve** of a typical Cepheid, together with the mean **velocity curve** plotted on the same time scale, is shown in the accompanying figure. (Light and velocity curves of W. Sagittarii.) The general characteristics of the curve are typical for all Cepheids with the rapid rise to maximum followed by a more gradual decline to minimum. The descending portion of the curve is char-



Light and velocity curves of W. Sagittarii. (*Cur-tiss in Lick Observatory Bulletins.*)

acterized in typical Cepheids by certain irregularities.

In the course of the study of typical Cepheids in the Small Magellanic cloud, Miss Leavitt, of the Harvard College Observatory, found a direct correlation between the average **magnitude** of the Cepheids and the period of variation. Since all variables in the cloud are at approximately the same distance from the earth, it appeared that the period of variation was directly correlated with intrinsic brightness or, in other words, with average **absolute magnitude**. Shapley, after an exhaustive study of numerous Cepheids with known distances and hence known average absolute magnitudes, was able to show that the correlation between period and luminosity was apparently characteristic of all Cepheids and, by plotting period against average absolute magnitude, obtained what is commonly known as the period-luminosity curve. After this curve is established, it is possible to determine the absolute magnitude of any Cepheid, no matter how distant, by simply determining the period. With the absolute magnitude and the apparent magnitude known, the calculation of the distance of the Cepheid is a relatively easy task. The period-luminosity relationship has been extended to the cluster type Cepheids and, while there is still some question as to the "zero point" of the various curves, it has served a very valuable purpose in determining distances of globular clusters.

Cepheid variables are also found in distant extragalactic **nebulae** and hence they may be used to determine distances of objects outside of our own **galactic system**. For this reason the Cepheids have been referred to as "the measuring rods of the universe." The explanation of the period-luminosity relation has not yet been found, but it may very probably be connected with the **mass-luminosity** relationship found by Eddington and others for all stars.

CEPHEUS. This constellation is particularly interesting because it contains the remarkable **variable star** δ Cephei. This star is the typical **Cepheid** variable, a class of stars which is most valuable in providing a measuring rod for probing the remote regions of space.

CERAMAL. A homogeneous mixture of one or more metals and a ceramic. (See **ceramet**.)

CERAMEL. Variation of **ceramal**.

CERAMET. A homogeneous mixture of one or more metals and ceramic material especially composed for combustion chamber throats where resistance to heating is most desirable, especially in rocket engines. (See also **cooling** and **combustion chamber**.)

CERAMICS. Any of a large group of clay-based porcelain, brick, or pottery type materials which become very hard after "firing" or baking at high temperatures. Ceramics have technical applications for insulators (such as spark-plug insulators), and dielectric structures in many types of electronic equipment. They are especially useful for heat-resistant uses; these are called **refractory ceramics**. Refractory ceramics are usually combinations of refractory oxides of the following elements: beryllium (BeO), aluminum (Al_2O_3), zirconium (ZrO_2), thorium (ThO_2), magnesium (MgO), and calcium (CaO). In rocket motors, ceramic or refractory materials (i.e., "firebrick" type substances) are sometimes used for throat stations because of their high resistance to heat penetration (i.e., lack of conductivity), and their high melting points. Because of their poor mechanical qualities, which unfortunately are even worse at high temperatures, ceramics are most often used merely as liners within a metal casing which provides the necessary support. Ce-

ramic liners allow longer operating times from simple temperature effects, but have two limiting characteristics. First, they are sensitive to erosion through chemical reaction with the hot combustion gases. Second, they are sensitive to sudden changes in temperature (thermal shock). Graphite and fiberglass are two substances sometimes used in place of ceramics for their lower temperature sensitivity. Ceramics are frequently used in filters. These are actually made of porous baked clay. The gasoline filter in automobile engine sediment bowls is a common example. These are inserted in fluid lines and high pressure gas lines to remove fine impurities or to dry the gas in passing.

CERIUM. Rare earth metallic element. Symbol Ce. Atomic Number 58.

CERMET. A coating for metal bases composed of chromium-boron-nickel. It is used for facing metal parts subject to severe erosion and oxidization.

CERTIFIED COMPONENT. A component (part, assembly) which has successfully passed a limited number of critical performance and environmental tests.

CESIUM. Metallic element. Symbol Cs. Atomic Number 55.

CETANE. A liquid paraffin hydrocarbon of formula $C_{16}H_{34}$.

CETANE NUMBER. The Cetane Number scale is derived from the standard practice of using a test fuel composed of cetane and alpha-methyl-naphthalene. Of these two, cetane has very good ignition qualities, whereas alpha-methyl-naphthalene is very poor. The Cetane Number of a fuel is the percentage of cetane, in a mixture with alpha-methyl-naphthalene which will give the same ignition quality as the fuel oil under test.

Cf. Californium.

CFAE. Contractor furnished aeronautical equipment.

CFE. Contractor furnished equipment.

CGS SYSTEM OF UNITS. Units and dimensions.

CHAFF. Electromagnetic-radiation reflectors in the form of narrow metallic strips used

to create radar echoes for confusion of enemy radars. Chaff represents one type of confusion reflector. (See **reflector**, **confusion**.)

CHAIN INSTRUMENTATION. Over long range proving grounds, short range instrumentation can be used by "tying" a number of separate instrumentation complexes into a single unit by feeding their outputs sequentially into some central recording location as the missile flies through the various complexes' sectors of coverage.

CHAIN RADAR SYSTEM. A series of tracking radar stations situated in line along a range flight line at convenient intervals. Tracking data from one set is used to position subsequent radars (i.e., "coach" them on target). All the sets are tied into a network which carry the target through its range and pass it on to the next radar. Data are normally recorded at some central location.

CHAIN REACTION. (1) A self-sustaining series of events. (2) A reaction in which one of the agents necessary to the reaction is itself produced by the reaction so as to cause like reactions. In the neutron-fission chain reaction, a neutron plus a fissionable atom causes a fission resulting in a number of neutrons which in turn cause other fissions.

CHAMBER ASCENT. A simulated ascent in an altitude chamber.

CHAMBER PRESSURE. In propulsion, the gaseous pressure generated in the motor chamber as the result of the combustion process. Combustion chamber pressure is directly proportional to the thrust derived from the motor. It is therefore desirable to have the chamber pressure as high as the structural limits of the rocket engine will allow. For liquid propellant rocket engines chamber pressures range between 300-500 psi. For solid propellant types pressures between 1000-3500 psi are common. Chamber pressure is abbreviated p_c . (See also **pressure** and **thrust**.)

CHAMBER, ROCKET MOTOR. The structurally enclosed space within which the rocket fuels are burned to achieve energy release in the form of high velocity hot gases. The passage of these gases from the rocket motor chamber through the exhaust nozzle produces thrust. The optimum motor chamber shape would be a sphere theoretically, but since this

is difficult to manufacture, practical chambers are usually cylindrical or modified cylinders.

CHANCE FAILURE. Failure modes.

CHANNEL. (1) In electromagnetic wave terminology, especially in communications, an assigned or predetermined band of frequencies or wavelengths. (2) In telemetry, the channel is the subcarrier oscillation which is modulated to carry the intelligence. The standard Dept. of Defense telemetry set-up has 16 telemetry channels carried on the main carrier. These channels may be either commutated or "straight." Commutated channels take a number of separate measurements and sample each of these in a time sequence, sending the resulting signal over the same subcarrier channel. This permits the use of one channel for many data elements but has the disadvantage that data readings are a fraction of a second apart. Straight channels record data continuously. In missile applications more than one type of continuous information can be sent on a single continuous channel during a given flight by programming the channel for one bit of information during the powered flight phase, another during the midcourse free-fall portion of the trajectory, and another during re-entry and terminal phase of flight. For example, the motor chamber pressure, cosmic ray count, and re-entry nose cone temperatures might all be recorded through use of the same telemetry channel, at different flight periods.

CHANNEL CAPACITY. The number of symbols per second which may be transmitted in a given channel.

CHANNEL, FREQUENCY. The band of frequencies which is associated with a single unit of intelligence in a communications system. Thus it applies to the band of frequencies radiated by a broadcast station, or to the band of frequencies which must be handled by a carrier system to handle a single conversation. In the various systems the application of intelligence to a given frequency will generate certain other frequencies which are then associated with the original in some manner to convey the intelligence to the receiver. This band of frequencies then determines the response characteristics which the receiver (or other units of the system) must have for satisfactory results. Thus in conventional

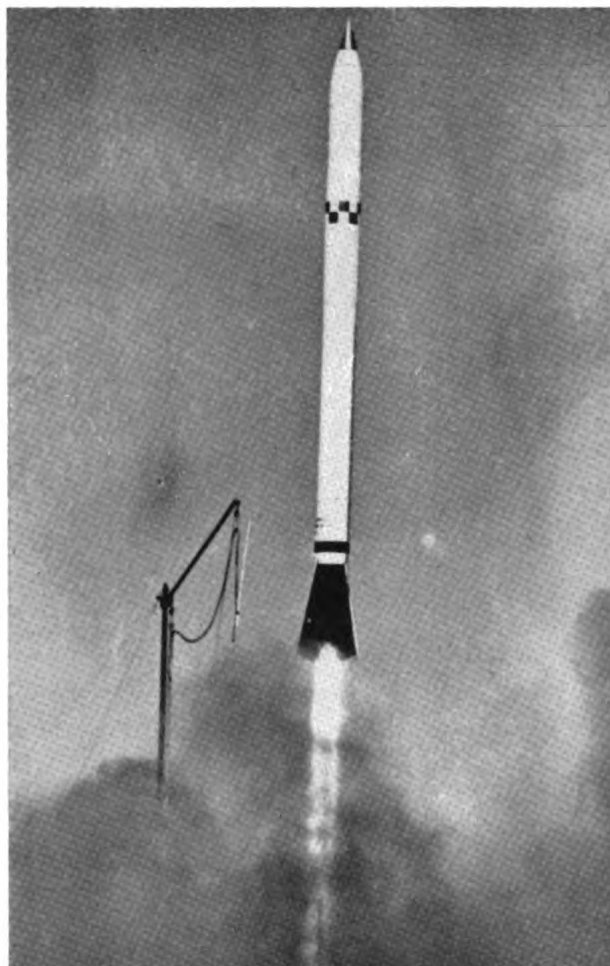
broadcasting the various stations use channels about 10 kc wide; in frequency modulation the present channel is about 200 kc; in television it is 5 or 6 megacycles; in carrier telephony it is only about 3 kc.

CHANNEL, TELEMETER. (1) The complete route for transmission of a telemetered function, including pick-up, commutator, modulator, transmitter, receiver, demodulator, decoder, and recorder. (2) A single source or channel of information.

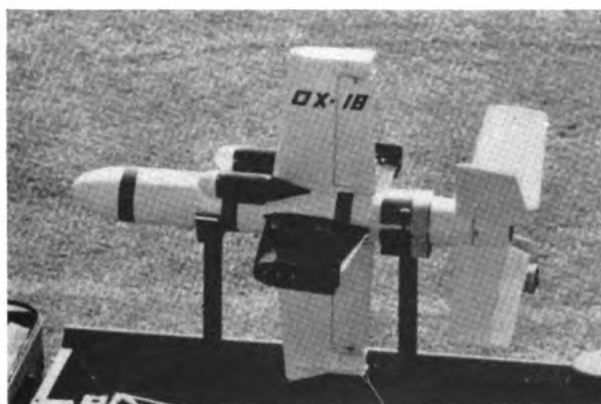
CHANNELIZED. A term pertaining to training, implying that a considerable amount of knowledge and skill peculiar to the equipment is required.

CHARACTER. (1) The trace (sum of the diagonal elements) of a matrix representation of a group. The character of all elements in a given class of the group is the same. (2) One of a set of elementary symbols which may be arranged in ordered aggregates to express information.

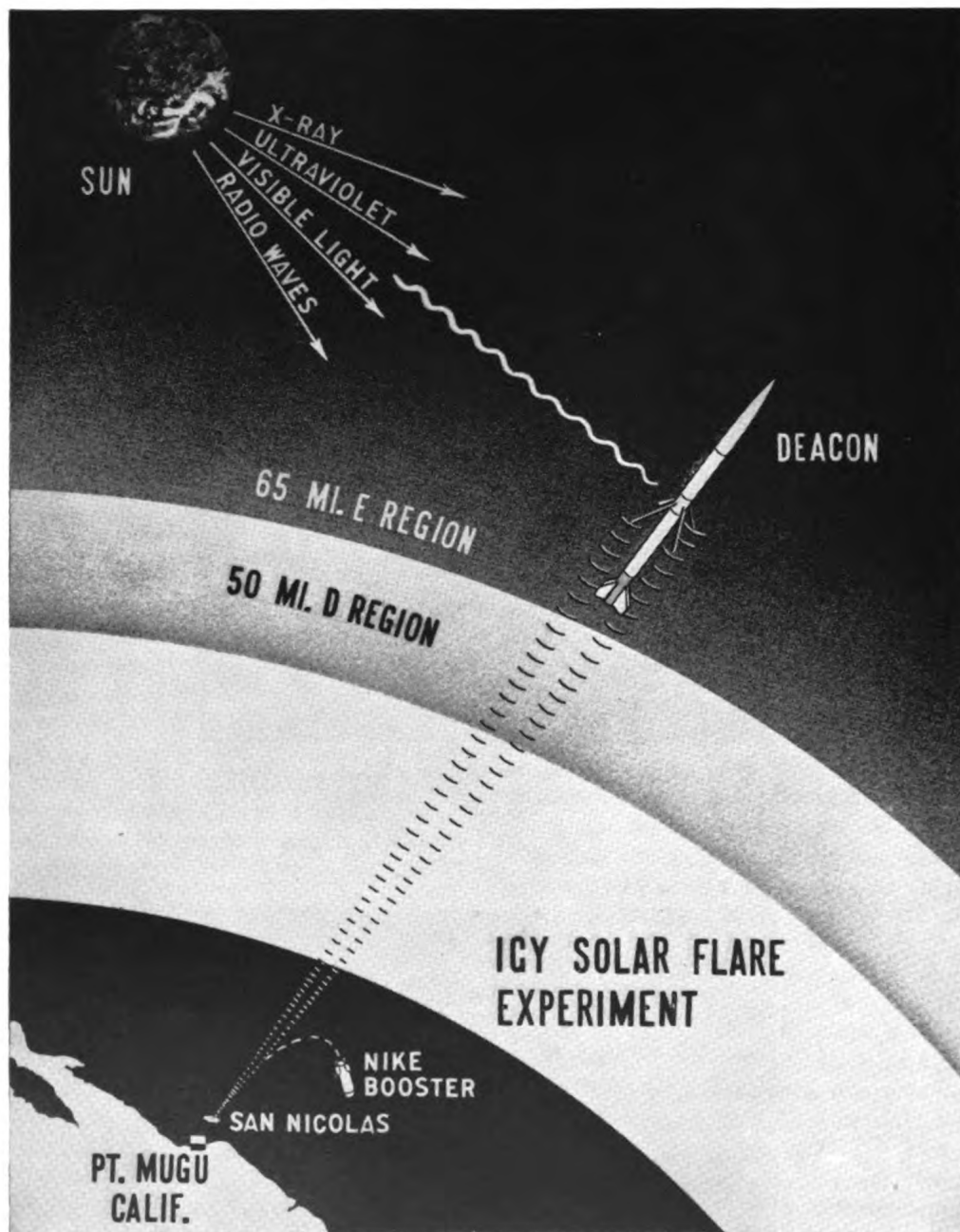
CHARACTERISTIC CURVE. (1) In aerodynamics, a graphical presentation of the characteristics of an airfoil plotted against various angles of attack. The parameters plotted are conventionally the coefficients of lift and drag, the lift-drag ratio, center of pressure, and the moment coefficient. (2) In supersonic aerodynamics, **Mach lines** are called characteristic curves. These are defined as a curve at any point in the stream which gives a Mach angle with the stream lines. The Mach number normal to a characteristic line is unity. (3) In electronics, a graphical representation of the relationship between important variables which affect the characteristics and operation of a component. (3a) For vacuum tubes, characteristic curves indicate the operating characteristics of the tubes. Generally, there are two types of curves: static characteristics, i.e., no load resistor on the plate circuit; and dynamic characteristics, where a load exists on the tube. Three properties are represented by these curves: I_p — plate current, e_g — grid voltage (with respect to cathode), and e_p — plate voltage. The transfer characteristics curve would plot I_p against e_g , with e_p held constant. This would result in a family of curves, one for each constant value of e_p . A plate characteristics curve would plot I_p



The CORPORA, U.S. Army's surface-to-surface guided missile, just after "take-off" at White Sands Proving Ground. (*U.S. Army Photograph*)



The guided missile, DART, is a simple but effective anti-tank missile. Inherent in the design is a high probability that a single hit shall destroy a heavily armored tank. This weapon system will be employed by Infantry or armored combat units. The missile is approximately five feet long with a configuration characterized by fins crossing its waistline. DART is propelled by a rocket motor containing smokeless propellant. The missile is sufficiently maneuverable to make it relatively safe from rifle, machine gun, and antiaircraft fire. (*U.S. Army Photograph*)



This artists' concept depicts the firing of a DEACON rocket with NIKE booster. (U.S. Navy Photograph)

against e_p , with e_c held constant. (4) In photography, the curve showing the relationship between exposure and resulting density in a photographic image. It is usually plotted as the density against the logarithm of the exposure in candle-meter-seconds. It is sometimes called the H & D curve or sensitometric curve.

CHARACTERISTIC EQUATION. (1) A class of equations connecting those variables, such as temperature, pressure, and volume, which define the physical condition of a given substance and are called variables of state.

The ideal gas law and the Boyle-Charles law represent approximately the behavior of all gases, but if one wishes to be accurate, some modification of these must be sought which will take account of the differences between individual gases. The best known characteristic equation for gases is that of van der Waals. Using the same notation as for the ideal gas law, this may be written

$$\left(p + \frac{a}{v^2}\right)(v - b) = RT.$$

(For other characteristic equations, see **equation of state**.)

CHARACTERISTIC IMPEDANCE. (1) The input impedance of an infinite length of line (which is finite, and is usually denoted by the abbreviation Z_0). The current in the line at any point is equal to the voltage at that point, divided by Z_0 . Mathematically, $Z_0 = 138 \log d_1/d_2$ (for a coaxial line) or $Z_0 = 276 \log 2D/d$, where d_1 is the inside diameter of the outer conductor, d_2 is the outside diameter of the inner conductor, D is the distance between wire centers, d is the diameter of conductors. The characteristics impedance of free space is $\eta = 377$ ohms. (See **impedance** and **transmission lines**.) (2) For waveguides the ratio of the rms voltage between midpoints of the two conductor faces normal to the electric vector and the total power flowing when the guide is match-terminated.

CHARACTERISTIC LENGTH. In propulsion, the ratio of the volume of a **combustion chamber** to its **nozzle throat area**. It is a measure of the length of travel available for the combustion of propellants. To obtain the best performance possible, the chemical reaction should be completed before the gaseous combustion products reach the entrance to the

exhaust nozzle. The objective is to minimize the characteristic length without introducing any significant reduction in the measured value of **characteristic velocity** due to incomplete reaction of propellants. The relationship is:

$$L^* = \frac{V_c}{A_t},$$

where L^* is the characteristic length, V_c is the chamber volume, and A_t is the nozzle throat area.

CHARACTERISTIC VELOCITY. In propulsion, the ratio of the exhaust jet velocity to the thrust coefficient, which is a measure of the effectiveness with which the chemical reactants of the propellants in the rocket motor produce the high-temperature, high-pressure gases. It is expressed by the relationships:

$$c^* = \frac{V_j}{C_f} = \frac{g}{dw/dt} p_c A_t = \frac{g}{c_w},$$

where c^* is the characteristic velocity, V_j is the exhaust jet velocity, C_f is the thrust coefficient, g is the acceleration of gravity, dw/dt is the flow rate of propellant by weight, p_c is the chamber pressure, A_t is the nozzle throat area, and c_w is the weight flow coefficient.

CHARACTERIZATION DEVICE. A device which adds or subtracts a value to a control signal in some predetermined relationship.

CHARACTRON. A form of **cathode-ray tube**. The display is in the form of letters or numbers.

CHARGE. (1) A quantity of **electricity**, measured in **coulombs** or related units. The flow of charge per unit time is the **electrical current**. (2) A term applied to flux, especially in the flux-charging concept of **magnetic amplifier** operation, commonly expressed as volt-time integral. (3) Used as a verb, charge denotes the act of passing a current through a secondary battery (see **battery**, **secondary**) in an opposite direction to that of discharge, so that the battery may operate as an effective source of electrical energy.

CHARGE, PROPELLANT. The solid stage **oxidizer** and **fuel** used in solid propellant rockets. The charge usually includes the **inhibitor**, which does not contribute to the total **impulse**.

CHARGE/WEIGHT RATIO. A term used in solid rocket design to ratio the weight of the **propellant** charge, including the inhibitor, to the total weight of the solid rocket (charge and metal parts) excluding special fittings and attachments. (See **metal parts/weight ratio**.)

CHARLES LAW. The coefficients of expansion of all gases are nearly the same, namely, about $\frac{1}{273}$ of the volume at 0°C per centigrade degree. The law, stated by Charles in 1787 and independently by Gay-Lussac in 1802 (hence sometimes called Gay-Lussac's law), is not strictly true for non-ideal gases. Regnault obtained the following values of the volume coefficient, at one atmosphere pressure, for various gases:

Air	0.0036706
Hydrogen	0.0036613
Carbon dioxide	0.0037099
Sulfur dioxide	0.0039028
Carbon monoxide ...	0.0036688
Nitrous oxide	0.0037195
Cyanogen	0.0038767

None of these is far from $\frac{1}{273} = 0.003663$, which is therefore commonly taken as the expansion coefficient for gases; especially as the value for hydrogen, commonly used in the standard gas thermometer, is very near it. If the pressure as well as the volume is allowed to vary, the behavior of the ideal gas must be expressed by the **Boyle-Charles law** or the **ideal gas law**, or of a real gas by one of the **equations of state**.

CHASSIS. The metallic base on which the parts of electronic circuits are mounted.

CHECK VALVE. A valve used to seal automatically the passage of a fluid against back-flow.

CHECKOUT. A test or procedure for determining whether a person or device is capable of performing a required operation or function. When used in connection with equipment, a checkout usually consists of the application of a series of operational and calibration tests in a certain sequence, with the requirement that the response of the device to each of these tests be within a predetermined tolerance. For personnel, the term checkout is sometimes used in the sense of a briefing or explanation to the person involved, rather than a test of that person's capabilities.

CHEMICAL ENGINE. An engine, especially a **jet engine**, that uses chemical **fuels** other than hydrocarbon fuels.

CHEMICAL MILLING. The controlled removal of metal by masking the part to be treated, then immersing it in an acid or alkaline etching bath at a controlled temperature for a carefully timed period. The process may be used on sheet, forgings or extrusions.

CHEMICAL PRESSURIZATION. The pressurization of propellant tanks in a rocket by means of high-pressure gases developed by the combustion of a fuel and oxidant or by the decomposition of a substance.

CHEMOPAUSE. The upper boundary of the **chemosphere**.

CHEMOSPHERE. According to some classifications of the earth's **atmosphere**, the region between 20-50 miles altitude. It is considered to be the area where photochemical activity is present. For example, the chemosphere is the region in which compressed nitric oxide gas released will cause two dissociated atoms of oxygen to unite into one oxygen molecule, and emit light. Experiments in the chemosphere have showed that the nitric oxide forms an ionized cloud which reflects radio signals just as the ionosphere does.

CHEST-TO-BACK ACCELERATION. Accelerating force acting on the human body in the direction from the chest to the back, as occurs when seated facing forward in an aircraft slowing down. It is a type of transverse acceleration.

CHLORELLA. A genus of unicellular green **algae**. Several species of this genus grow very well in artificial media and have been used for many years in experiments on **metabolism** in plant cells. These green cells have been especially valuable in studying **photosynthesis**. Since the organism is unicellular, many of the complications caused by the complex structure of leaves are avoided. Recently *Chlorella* has been investigated as a possible source of food for humans, possibly for space travel. A less remote use is for oxygen replenishment in space ships, since oxygen is a by-product of their metabolism. If the cells are provided with adequate light and a nutrient solution of suitable composition, they grow rapidly, producing large masses of plant ma-

terial. Investigators have selected strains of *Chlorella*, especially of *C. pyrenoidosa* and *C. ellipsoidea*, which will produce high percentages of proteins, carbohydrates, or fats. Thus almost any desired class of foods could be produced. Experiments have shown that foods prepared from these algae can be quite palatable.

CHLORINE. Non-metallic gaseous element. Symbol Cl. Atomic number 17.

CHLORINE TRIFLUORIDE. A possible oxidant for rocket fuels. Its formula is ClF_3 . It has a boiling point of 54°F , freezing point -117°F , and a specific gravity of 1.77.

CHOKE COIL. An element of inductance used in electrical circuits primarily to present high reactance at certain frequencies. Such coils usually have high reactance compared to their resistance, and offer impedance to the flow of alternating currents by the induced counterelectromotive force. Since this impedance varies directly with frequency, the choke may be designed to let certain lower frequencies through and stop or impede higher ones.

CHOKE-INPUT FILTER. Filter, choke-input.

CHOKING. A condition which arises when a compressible fluid has reached its maximum limit of mass flow. In an ordinary tapered nozzle or duct, choking limits the maximum mass flow to Mach 1. In the supersonic nozzle, this choking is relieved by diverging the nozzle after the duct constriction. This allows expansion of the flow and an increase in the speed of flow.

CHOKES. A form of altitude sickness characterized by coughing, a deep and usually burning irritation in the lungs, and shallow breathing.

CHOPPER. (1) A device, usually mechanical, to impart a pulsating characteristic to a current or a beam of light by a regular and frequent interruption. (2) A device which modulates a signal by opening and closing contacts periodically. The frequency of the chopper is usually greater than any frequency of interest in the signal.

CHORD, AIRFOIL. A basic reference axis for the geometric or aerodynamic properties of

an **airfoil**. It is normal to the span and lies in the plane of the airfoil. There are two of these reference chords. The one used for general and structural reference is the *geometric chord*. The other is an *aerodynamic chord*, being an imaginary line through the airfoil parallel to the free air stream at zero lift and passing through the trailing edge. The length of this chord is of no importance. It is useful mainly in aerodynamic studies because the lift varies directly with the **angle of attack** of the aerodynamic chord.

If the airfoil has a flat lower surface an element of this surface is taken as the geometric chord. The chord length is the over-all projection of the profile on this chord. In double-cambered airfoils the geometric chord is taken as the longest straight line possible between leading and trailing edges, or as a straight line joining the ends of the profile median line. The angle of attack to the geometric chord at zero lift is the angle between these chords. This may be discovered by wind tunnel tests, although empirical constructions have been devised which locate the aerodynamic chord surprisingly well. If the wing is tapered there is a *tip chord* and a *root chord*. The location of the intermediate chord on which the aerodynamic forces could be assumed to act is called the mean aerodynamic chord and is important in studies of airplane balance and stability. When the coefficient of lift may be assumed to be constant over the semi-span, the mean aerodynamic chord coincides with the mean geometric chord (i.e., the centroid of the semi-wing planform). This simplification is in error if the wing has twist, or if it is rectangular, in which case the uneven downwash causes decreased lift coefficient near the tips. It is an excellent approximation for untwisted tapered wings and exact for untwisted elliptical wings.

CHORD DIRECTION. The direction parallel to the intersection of the plane of the internal wing truss with the plane of symmetry of the air-vehicle. When a wing has two internal trusses in non-parallel planes, the plane bisecting the dihedral angle between those two planes should be used.

CHORD LENGTH. The length of the projection of the airfoil section on its **chord**.

CHROMACARB. A coating applied to high carbon materials, so that the chromium com-

bines with carbon to form chromium carbide. The resulting surface has the microhardness of a carbide material, giving wear and oxidation resistance.

CHROMIUM. Metallic element. Symbol Cr. Atomic Number 24.

CHROMODIZE. A surface treatment for metals, in which chromic acid and other reagents are used to produce a protective coating.

CHROMOSPHERE. The chromosphere is the layer of **atmosphere** of the sun which is composed principally of hydrogen, helium and calcium. It lies at a distance of several hundred miles above the **photosphere** and merges into the **reversing layer** below and the **corona** above. Since the elements which compose the chromosphere contain strong spectral lines in the red, it is usually visible at a total **eclipse** of the sun as a brilliant red envelope about the sun, and gets its name from this fact. The chromosphere may be observed with specially designed instruments, similar to those used in the study of **prominences**, even without a total eclipse.

CHRONOGRAPH. An instrument designed for measuring and recording short periods of time to great accuracy. In ballistic applications, a **chronograph** is used to measure the length of time it takes a projectile to travel a certain distance. (Thus, muzzle velocities and other trajectory velocities may be calculated.)

CHRONOMETER. An accurate timepiece. The chronometer is merely a precisely accurate watch or clock.

CHRONOTRON. (1) A device which utilizes a measurement of the position of the superposed loci of a pair of **pulses** on a transmission line to determine the time between the events which initiate the pulses. (2) A trade name for a time-delay device.

CHUFFING (CHUGGING) (COMBUSTION RESONANCE). The characteristic of certain rockets to burn intermittently with relatively low frequency pressure oscillations and with an irregular puffing noise.

CHUGGING. Chuffing.

CIA. Central Intelligence Agency.

CINETHEODOLITE. A **phototheodolite**.

CIRCLE. A plane curve such that all of its points are at a fixed distance, its **radius**, from a fixed point, its **center**. Its general equation in rectangular coordinates is given by

$$x^2 + y^2 + 2Ax + 2By + C = 0$$

provided $D = A^2 + B^2 - C$ is positive and does not vanish. Under these circumstances, the radius of the circle is \sqrt{D} and its center is at $x = -A$, $y = -B$. If $D = 0$, the circle degenerates into a point; if D becomes negative the circle is imaginary.

If the equation is transformed to new axes parallel to the original axes and the origin so chosen that terms in x and y are eliminated, the standard equation of the circle becomes

$$x^2 + y^2 = r^2$$

where r is its radius.

CIRCLE OF CONFUSION. Due to imperfect imagery and to the fact that the images of points at different object distances are commonly observed on a single image-plane (e.g., the film in a camera), the image of a point object is, in general, a small circle, the circle of confusion.

CIRCLE OF EQUAL ALTITUDE. A circle about any point at which the angular altitude of a given celestial body is the same. Two overlapping circles of equal altitude provide a fix, with the aid of dead reckoning, at one of the two points where the circles intersect. Also called a "circle of position."

CIRCUIT (ELECTRIC). A characterization of an electrical system in terms of the integrated effects of the electric and magnetic fields present in the system. The characterization is an approximation to the actual field problem in which one replaces the actual system by elements having **resistance**, **capacitance**, and **inductance** and by sources of **electric potential** and **electric current**. Systems in which the approximation cited is permissible are sometimes called "lumped constant" circuits. Antennas and transmission lines, on the other hand, are often referred to as "distributed constant" circuits. The distinction between these two designations comes from the spatial variation of the electric and magnetic fields as outlined above.

As may be inferred from the definitions, the

parameters of resistance, capacitance, and inductance are not necessarily independent of the currents and voltages impressed upon the elements of an electrical system. Whether the resistance of an element is a function of the current through it or not, the relation $v = Ri$ (R is resistance in ohms) is still valid for the connection between the voltage across an element and the current through it. On the other hand, corresponding relations for the coil and the capacitor become more involved if their parameters are dependent on current or voltage. For constant parameters of inductance (L in henrys) and capacitance (C in farads), the voltages and currents in pure inductive and capacitive components assume the form

$$v = L \frac{di}{dt} \quad \text{or} \quad i = \frac{1}{L} \int v dt$$

and

$$i = C \frac{dv}{dt} \quad \text{or} \quad v = \frac{1}{C} \int i dt$$

respectively. If the parameters L and C vary with impressed voltage and current, the above relations are not valid and recourse must be made to the basic law of **electromagnetic induction** when coils are involved and to the expression for electric current as the rate of change of charge (derivative of charge with respect to time) for circuits containing capacitors.

Whether elements with constant or variable parameters are involved, one may employ **Kirchhoff's Laws of Networks** to formulate equations representing conditions of equilibrium between the applied voltages and/or currents and the quantities that result. The equilibrium equations may be formulated on the basis of voltages as independent variables and currents as dependent quantities, the system of equations being known as the mesh equations for the circuit. Alternatively, they may be written on the nodal basis, where the sources are current generators and the dependent quantities are nodal voltage differ-

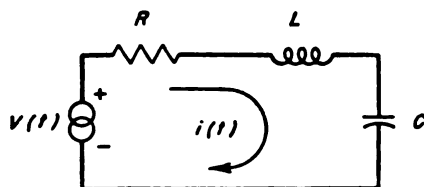


Fig. 1

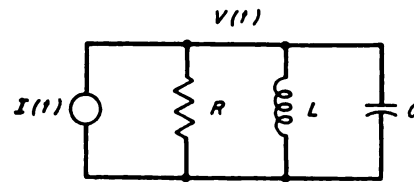


Fig. 2

ences with respect to a reference node. As an example of the process involved, consider the simple series circuit shown in Fig. 1 and the simple parallel circuit shown in Fig. 2 above.

The single mesh equation characterizing the series circuit and the single nodal equation describing equilibrium in the parallel circuit are, respectively

$$V(t) = Ri(t) + L \frac{di(t)}{dt} + \frac{1}{C} \int i(t) dt$$

and

$$I(t) = \frac{1}{R} v(t) + \frac{1}{L} \int v(t) dt + C \frac{dv(t)}{dt}.$$

The mesh and nodal equations for more complicated circuits have a form similar to these equations with added dependent variable terms and, in general, additional independent variable terms. The equations may be solved by various mathematical means to yield the desired unknown quantities, currents for mesh equations and voltages for nodal equations.

CIRCUIT, BALANCED. A circuit, all of whose impedors are symmetrically disposed with respect to objects at ground potential.

CIRCUIT BREAKER. An electrical device designed to open an electrical circuit under predetermined conditions, either normal or abnormal. They may trip because of overload, undervoltage or because of other conditions, usually undesirable to the circuit. An oil circuit breaker is one in which the contacts are immersed in oil so that any arc initiated is extinguished.

CIRCUIT, CLIPPING. (1) A circuit for preventing the peak amplitude of an electrical signal from exceeding a predetermined level. (2) A circuit for eliminating the tail of an electrical pulse after a predetermined time. (3) A circuit element in a **pulse amplifier** for reducing the amplification at frequencies below a predetermined frequency.

CIRCUIT, COINCIDENCE. Coincidence circuit.

CIRCUIT, COUPLED. While any group of circuits which are so connected or related that effects in one produce effects in the other constitute a coupled circuit, the term is usually used to designate circuits related so a-c effects are transferred but steady state d-c effects are not. The two most common classifications of coupled circuits are the inductive and the capacitive coupled circuits, so named because of the primary method of transferring the effects. Capacitance coupling is used quite extensively in various vacuum tube amplifier circuits, in thyratron circuits, and similar applications where it is desired to block d-c effects and transfer a-c. Since the capacitor does this it may be used as the common element between the two circuits. The so-called resistance coupled amplifier is really capacitance coupled. Fig. 1 shows examples

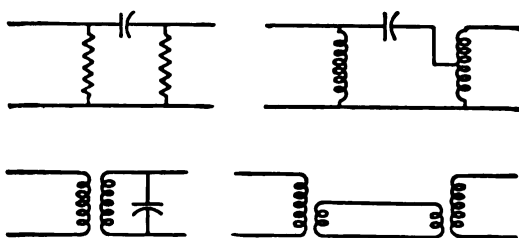


Fig. 1. Capacitance coupled circuits (top).

Fig. 2. Inductance coupled circuits (bottom).

of this type. Inductive coupling is the most widely used type since it is used extensively in the power field as well as in the communications and electronics fields. The ordinary power transformer is the means of inductively coupling two power circuits. The various transformers, tuning coils, etc., of radio circuits are other examples. Fig. 2 shows some typical circuits.

CIRCUIT DIAGRAM. A line drawing used in electrical and electronic theory and maintenance showing specific wire connections, and individual parts such as resistors, potentiometers, coils, and capacitors.

CIRCUIT, FLIP-FLOP. Monostable circuit.

CIRCUIT, INTEGRATING. A circuit whose output current or voltage is proportional to the time integral of its input current or voltage.

CIRCUIT, NATURAL FREQUENCY OF.

A simple tuned-circuit responds to an impulse by ringing, or by producing an exponentially-decaying, sinusoidal oscillation. The frequency of this oscillation is the natural frequency of the circuit. It is given by

$$f = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}},$$

for a circuit composed of a resistance R , an inductance L and a capacitance C , all connected in series. Circuits of greater complexity may often be reduced to an equivalent series circuit, although some may have more than one natural frequency and hence constitute coupled oscillators.

CIRCUIT, PUSH-PULL. Push-pull circuit.

CIRCUIT, QUENCHING. A circuit which diminishes, suppresses or reverses the voltage applied to a counter tube in order to inhibit multiple discharges from a single ionizing event.

CIRCUIT, SCRAMBLER. A circuit, usually consisting of a balanced modulator and appropriate filters, for the production of scrambled or inverted speech.

CIRCUIT, TIME CONSTANT OF A. The time required for the current in a circuit, or the potential difference across some element of the circuit to reach $1 - 1/e$ or about 63% of its final value after having had a step-function signal applied.

CIRCUIT, VOLTAGE-DOUBLER. Voltage doubler.

CIRCUIT(S), VOLTAGE SUPPLY AND REGULATOR. Any of a large number of circuits whose function is to provide d-c voltage for use as plate and filament supply voltage. Regulated supplies maintain the output voltage essentially constant under conditions of varying output current and/or line voltage.

CIRCULAR ERROR PROBABLE (CEP) ALSO CIRCULAR PROBABLE ERROR (CPE). A term describing the hitting accuracy of a guided missile or artillery shell measured at the target in a plane perpendicular to the trajectory for air targets and in the ground plane for surface targets. Thus, it is

that error which is just as likely to be exceeded as not. It is the radius of a circle that encompasses 50% of the probable points of impact.

CIRCULAR MAGNETIC WAVE. Wave, circular magnetic.

CIRCULAR MIL. A unit used to measure the cross-section of an electric conductor. One circular mil (abbreviated cir mil or cm), is the area of a circle 1/1000th inch in diameter. The area of a circle 1 inch in diameter is 1,000,000 cir mil (actually 0.7854 in²). To convert square inches to circular mils divide circular mils by 1,273,000 or multiply circular mils by 0.7854 and divide by 1,000,000.

CIRCULAR PROBABLE ERROR (CPE). Circular error probable.

CIRCULAR SCANNING. Radar scanning in which the direction of maximum radiation (the radar beam) sweeps in a circle, or a right circular cone whose vertex is close to 180°, around the transmitting antenna. (See also conical scanning.)

CIRCULAR VELOCITY. (1) The velocity of a body whose orbit is a great circle on an equipotential surface of a central force field. (See also center of attraction.) (2) The velocity at which a body must move to orbit the earth at a constant height just above the tangible atmosphere. (About 25,000 fps.) The circular velocity compensates for losses due to drag and gravity. (See also escape velocity and orbital velocity.)

CIRCULATING MEMORY. In computer work, a memory consisting of a means for delaying information, and means for regenerating and reinserting the information into the delaying means.

CIRCUMPLANETARY ORBIT. Orbit, circumplanetary.

CIRCUMSOLAR ORBIT. Orbit, circum-solar.

CIRCUMTELLURIAN. Circumterrestrial.

CIRCUMTERRESTRIAL. About the earth, e.g., designating an object having an orbit like that of the moon, or a circumterrestrial satellite.

CIRCUMTERRESTRIAL SATELLITES.

All space vehicles moving about the earth as their principal center of attraction. The lunar probes, on the other hand, operate near or on the moon. The circumterrestrial satellites include terrestrial satellites, cislunar satellites and translunar satellites. (See table under instrumental vehicles for space research.)

CIRROCUMULUS. Small billowed cirrus-type cloud composed of ice crystals. This type cloud indicates some instability in the layer at and above the cloud level which permits rising currents to form the cloud parcels and descending currents to create clear spaces between them. Cirrocumulus frequently occurs in advance of a cyclonic storm.

CIRROSTRATUS. Cloud veil of more or less uniform texture composed of ice crystals and therefore, like cirrus, lying entirely above the freezing level. Cirrostratus varies from white to gray, is usually translucent, and partially obscures the sun and moon. There are no shadows but often mock-suns or mock-moons which are images of the real celestial bodies. Cirrostratus often heralds the approach of a cyclonic storm, particularly in the temperate zone.

CIRRUS. High cloud composed of ice crystals and, therefore, lying entirely above the freezing level. Cirrus is never lower than about 4 miles in the tropics, but may be near ground levels in the polar areas. In appearance they are usually thin, wispy, often in streaks, and always whitish without shadows. Cirrus often forerun storms but not all cirrus are associated with storms. They cannot be used as a foolproof indication that a storm is approaching until considerable experience in cloud observation is attained.

CISLUNAR. (1) Pertaining to the moon. (2) Pertaining to the region of the earth-side of the moon. The term is frequently applied to solar-powered craft which require exposure to the sun for operation. They are thus said to be restricted to cislunar space.

CISLUNAR SATELLITE. A satellite designed to move in an orbit which is distant from the center of the earth an amount from twice to thirty times the radius of the earth (if this orbit is circular); or at a distance of twice to one hundred times the radius of the

earth (if this orbit is the major axis of an ellipse): the cislunar satellite, therefore, operates essentially in the space inside the lunar orbit. The distinction between a terrestrial and a cislunar satellite cannot be drawn very sharply. However, at a distance of two earth's radii from the center of the earth, a satellite is essentially outside the space of immediate terrestrial influence, except for the gravitational and magnetic fields. At about 1,000 kilometers from the earth the mean free path of atmospheric molecules is assumed to become several kilometers in length, enabling sufficiently fast neutral atoms and molecules to diffuse into interplanetary space. Ionized gases are held by the earth to greater altitudes, owing to the earth's magnetic field. However, the magnetic field strength decreases with the distance inversely proportionate to $(r/r_E)^3$ where r is the distance from the earth's center and r_E the earth's radius.

The orbits of cislunar satellites range from high-altitude circular orbits, notably the so-called 24-hour orbit at about 19,000 nautical miles altitude, to elliptic orbits of high eccentricity, reaching out into the lunar orbit. In cases of close hyperbolic lunar passage, lunar attraction becomes dominant, changes the orbit significantly, and may even throw the satellite out of the earth-moon system entirely. Generally however, the earth is the dominant factor, and therefore both the terrestrial and the cislunar satellite can be regarded as members of the more basic group of **circumterrestrial satellites**.

CISPLANETARY SPACE. Space, cisplanetary.

CIVIL TIME. Time based upon an imaginary sun assumed to be traveling along the path of the real sun with the mean motion of the real sun. Civil time is used in order to have uniform units of time. Civil time is governed by the elapsed time between two successive transits of the mean sun over a given meridian. It is also known as standard time or mean solar time.

C_L. Lift coefficient; coefficient of moment (rolling)

Cl. Chlorine.

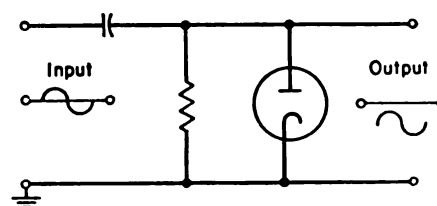
CLAD STEEL. A composite steel (plate) made up of a commercial grade of steel plate, upon one or both sides of which is joined a

veneer or cladding of corrosion-resistant or heat-resistant metal. To be a clad product the thickness of the coating must be a substantial proportion of the total plate thickness. Claddings for steel are stainless steel, nickel, Monel, silver, copper, Inconel, or cupro-nickel.

CLAIRON. A hypothetical planet of our solar system so situated in its orbit as to be invisible from earth. Most professional astronomers discredit the concept. It was conceived to account for anomalies measured in the paths of the planets.

CLAMPING. The connection of some point of a circuit to a desired reference potential for certain periods of time. Sometimes called d-c restoration. (See **clamping circuit**.)

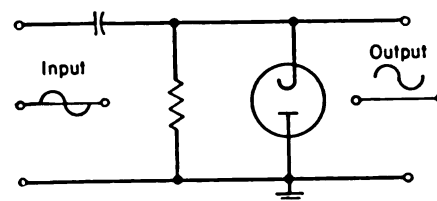
CLAMPING CIRCUIT. A circuit which holds either the maximum or minimum amplitude of a signal at a given voltage level. They are sometimes called "d-c restorers" or "base line stabilizers." A clamping circuit does not change the waveform. It may clamp either positively or negatively depending upon



(a)

Negative diode clamping circuit.

whether the signal is held below or above some given reference level. The output of a clamper is really a varying d-c voltage rather than a-c. The direction in which a waveform is clamped is determined by the tube connections. If the cathode is connected to ground, the circuit will clamp negatively. The output of the clamper does not change, it merely ad-



(b)

Positive diode clamping circuit.

justs the zero reference. Clampers can be either of the diode (see figure) or triode types.

CLARK "Y." A type of airfoil cross-section. The name "Clark" refers to a whole family of airfoil sections. Clark "Y" is a cambered type with 6% maximum thickness 33% back from the leading edge and with 30% camber. This section is widely used for propeller blade cross-sections. (See also **airfoil nomenclature**.)

CLARKE CELL. An electrolytic cell used as a source of standard electromotive force for calibration and testing purposes, where large currents need not be drawn. It has a mercury cathode and an amalgamated zinc anode. The cathode is submerged in a mercurous sulfate paste, and the electrolyte is a solution of zinc sulfate saturated at 0°C. The whole is sealed in a suitable glass tube. This cell has an electromotive force of 1.440 volts at 15°C., with a temperature variation of 0.00056 volt per degree Centigrade.

CLASS-A AMPLIFIER. Amplifier, class-A.

CLASS-A MODULATOR. Modulator, class-A.

CLASS-AB AMPLIFIER. Amplifier, class-AB.

CLASS-B AMPLIFIER. Amplifier, class-B.

CLASS-B MODULATOR. Modulator, class-B.

CLASS-C AMPLIFIER. Amplifier, class-C.

CLASSIFICATION OF DEFECTS. A method of establishing acceptability of a product. The classification establishes need for rework or changes to meet a specification. In U.S. Air Force terminology, the authorized classifications of equipment are: (1) Development type, (2) Adopted type, (2a) Tentative standard, (2b) Standard, (2c) Substitute standard, (2d) Limited standard, (4) Obsolete.

CLASSIFIED. A security term designating material or information whose disclosure to a prospective enemy would be inimical to the national interest.

CLEANUP. (1) The removal of gas from a high-vacuum tube by the action of the

getter. (2) The gradual disappearance of gas in a discharge tube (such as a cold cathode-ray tube or an x-ray tube) due to absorption by the electrodes and glass walls.

CLIMATIC TEST. A generic term describing any test designed to evaluate the ability of equipment to survive climatic conditions. Climatic tests usually include: sunshine, rain, hail, snow, sleet, wind, humidity, aridity, sand, dust, temperature, fungus, salt spray, etc.

CLINODROMIC. Heading at a constant lead angle with respect to the target or objective.

CLINOMETER. An instrument for measuring angle of inclination (slope). It is applied to objects traveling in the atmosphere or space, e.g., missiles, airplanes or clouds.

CLIPPER. In communications, a circuit which does not permit the positive (or negative) level of a signal to exceed a certain value.

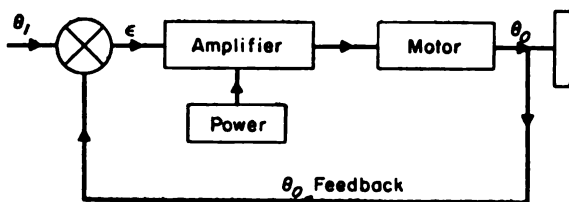
CLIPPING. (1) Distortion in amplifiers produced by flattening of plate current curve due to excessive grid current during positive grid swing. (2) Distortion in the audio frequency component of a modulated wave when modulation amplitude exceeds that which brings the trough to zero. (3) Generation of approximately square waves by shunting biased diodes across the load, the bias determining the amplitude at which the peaks are to be clipped.

CLIPPING CIRCUIT. Circuit, clipping.

CLIPPING TIME. The time constant of the clipping circuit. (See **circuit, clipping** (2) and (3).)

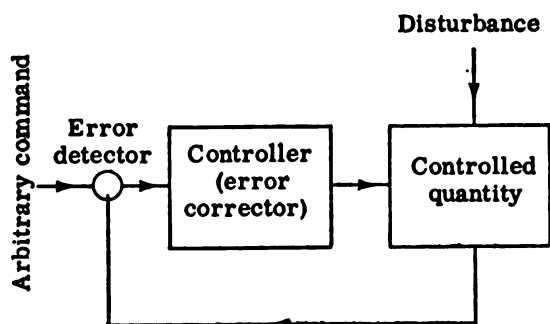
CLOCK PARADOX. If two identical clocks A, B, are synchronized and then A is accelerated arbitrarily and brought back to compare with B, which has not been accelerated, then A will record a shorter time interval than B. This conclusion is a consequence of, and is understandable in terms of, **relativity theory**.

CLOSED CYCLE (LOOP) CONTROL SYSTEM. A servo system utilizing **feedback** from the output to the input to measure its own response to errors, and correct for them. (See figure on Page 131.)



Closed cycle (loop) control system.

CLOSED LOOP. A family of automatic control units linked together with a process to form an endless chain. The effects of control



Basic elements of a closed loop system.

action are constantly measured so that if the controlled quantity departs from the norm, the control units act to bring it back. (See figure.)

CLOSED LOOP TESTING. A test technique in which all dynamic elements of the missile system, including the guidance and aerodynamic characteristics, are physically used or simulated with all loops closed as in flight.

CLOSED ORBIT. Orbit, closed.

CLOSED SYSTEM. A system which is isolated from its surroundings, and which may therefore reach a state of thermodynamic equilibrium, i.e., a time-invariant state where all macroscopic quantities remain unchanged and no spontaneous processes occur.

CLOSEST APPROACH. The place or time at which two planets are nearest to each other as they move in their orbits about the sun.

CLOUD. Large numbers of water droplets or ice crystals virtually suspended in the atmosphere. Actually the water or ice in a cloud occupies only a small fraction of the total space appearing as a cloud. Light is well reflected from the droplets or crystals and the cloud body appears as an opaque drifting object. Clouds can be classified in

several ways. The two most common are in regard to form, stratified or billowed; and in regard to height, high, medium, or low. The basic cloud forms are internationally recognized but there are many variations of each form. The basic forms of clouds are: (1) high clouds (*cirrus*, *cirrocumulus* and *cirrostratus*); (2) middle clouds (*altocumulus* and *altostratus*); (3) low clouds (*stratocumulus*, *stratus*, *nimbostratus* and *fractostratus*); (4) clouds with vertical development (*cumulus* and *cumulonimbus*, *fracto-cumulus*, *mamato-cumulus*). (For visibility conditions see *Sky Symbols*.)

CLOUD COVER. An expression of the portion of the total sky that is obscured by clouds, e.g., 10/10 coverage is complete overcast.

CLUSTER. A grouping together of solid or liquid rocket engines to provide a launching carriage or booster assembly.

CLUSTER MISSILE. Missile, parallel cluster.

CLUTTER. In radar, miscellaneous "hash" or other visible signals on a radar scope which must be distinguished from, and tend to obscure target returns. Clutter is caused by returns from nearby objects, mountains, vegetation, buildings, and other reflecting bodies. At low angles of radar observation clutter is most objectionable. As track is elevated, the clutter becomes less of a problem. Clutter is also called "background."

C_M. Coefficient of moment (pitching).

Cm. Curium.

C_N. Coefficient of moment (yawing); normal force coefficient.

CNO. Chief of Naval Operations.

Co. Cobalt.

COASTER. A type of missile having no internal power, but using boosters which detach after burn-out leaving the missile to "coast."

COASTING FLIGHT. The flight of a rocket, missile or vehicle between burn-out or thrust cutoff of one stage and ignition of another, or between burn-out and summit altitude (if constrained to move along a straight line) or maximum range (if a ballistic trajectory ensues).

COATED LENS. An optical lens whose air-glass surfaces have been coated with a thin transparent film having an index of refraction which minimizes the light loss by reflection.

COAXIAL. Having the same axis.

COAXIAL ANTENNA. Antenna, coaxial.

COAXIAL LINE. A transmission line in which one conductor completely surrounds the other, the two being coaxial and separated by a continuous solid dielectric or by dielectric spacers with gas as the principal insulating material. Such a line is characterized by no external field, and by having no susceptibility to external fields from other sources.

COBALT. Metallic element. Symbol Co. Atomic Number 27.

COBALT BOMB. An atomic or hydrogen bomb encased in cobalt, which would be transformed into highly radioactive dust upon detonation.

COBRA. (1) A U.S. ramjet type missile intended as a research airframe for the Navy's

"Bumblebee" Project. The missile weighed 70 pounds and was approximately 6 inches in diameter. Take-off was rocket-boosted. (2) A Swiss solid-propellant rocket anti-tank missile, wire-controlled and similar to the French SS-10. It weighed 24 pounds, and had a range of about 1 mile.

COC. Air Division Combat Operations Center.

CODAGRAPH. An automatic curve plotter working from punched cards.

CODAN. Abbreviation for carrier operated device, anti-noise. A device which silences a receiver except when a modulated carrier signal is being received.

CODE. (1) A system of symbols and rules for use in representing information. (2) Loosely, the set of characters resulting from the use of code. (3) To express given information by means of a code. (See also **language**.) (4) A predetermined modulation pattern used in radio command signals to augment security against enemy electronic countermeasures.

CODE, INTERNATIONAL MORSE.

INTERNATIONAL MORSE CODE

A	. —	1	. — — — —
B	— . . .	2	. . — — —
C	— . — .	3	. . . — —
D	— . .	4 —
E	.	5
F	. . — .	6	—
G	— — .	7	— — . . .
H	8	— — — . .
I	. .	9	— — — — .
J	. — — — —	0	— — — — —
K	— . —		
L	. — . .	Period	. — . — . —
M	— —	Comma	— — . . — —
N	— .	Interrogation	. . — — . .
O	— — —	Quotation	. — . . — .
P	. — — .	Colon	— — — . . .
Q	— — . —	Semicolon	— . — . . .
R	. — .	Parenthesis	— . — — . —
S	. . .	Wait sign (AS)	. — . . .
T	—	Double dash (Break)	— . . . —
U	. . —	Error
V	. . . —	Fraction bar (/)	— . . — .
W	. — —	End of message (AR)	. — . — .
X	— . . —	End of transmission (SK)	. . . — . —
Y	— . — —	International distress signal (SOS)	. . . — — . . .
Z	— — . .	Message received (R)	. — .

CODE NAME. A generic code name assigned to each U.S. guided missile to permit convenient reference to it in unclassified correspondence and oral discussions (e.g., Nike, Talos, Atlas, Bomarc).

CODECLINATION. Polar distance.

CODER. A device which samples the modulating signal at regular intervals in a pulse-code modulation system.

CODORAC. Coded Doppler Radar Command system (of guidance).

COEFFICIENT A. The coefficient of constant compass **deviation**, caused by misplacement of the lubber line of a compass in relation to the longitudinal axis of the carrying vehicle.

COEFFICIENT B. The coefficient of semi-circular compass **deviation** caused by magnetism in the body of the carrying vehicle along its longitudinal axis.

COEFFICIENT C. The coefficient of semi-circular compass **deviation** caused by magnetism in the body of the carrying vehicle along its lateral axis.

COEFFICIENT D. A quadrantal **deviation** in a compass caused by temporary magnetism induced in the body of the carrying vehicle by the presence of soft iron in the load or equipment being carried.

COEFFICIENT E. A quadrantal compass **deviation** of negligible effect.

COEFFICIENT OF DRAG. In aerodynamics, a convenient dimensionless coefficient equal to the total drag of the body divided by the dynamic pressure and reference area.

$C_D = \frac{D}{qS}$, where C_D is the coefficient of drag, D is the total drag, q is the dynamic pressure ($q = \frac{1}{2} \rho_0 v^2$), and S is the projected area of the airfoil on a plane containing the chord and is perpendicular to the section of the airfoil. It is a function of the airfoil shape and the angle of attack. For rockets (or other bodies of the same shape), C_D is reasonably independent of the density of the air or the diameter of the body. For low velocities, C_D is reasonably independent of velocity. When the velocity of the rocket approaches the velocity of sound, the

air compressibility effects begin to be felt and C_D increases suddenly. The coefficient of drag also depends upon the yaw of the rocket, since this affects the volume of air disturbed.

COEFFICIENT OF FORCE. In aerodynamics, three basic effects operate on a body—*lift, drag and moments*. It is often convenient in theoretical computations to apply these quantities in the form of dimensionless coefficients. The force coefficients are such by definition. In addition to having coefficients of each of the three aerodynamic forces, there are also coefficients of the resultant of appropriate combinations of these into either the normal or longitudinal directions (e.g., normal force coefficient, longitudinal force coefficient, or resultant force coefficient).

COEFFICIENT OF LIFT. In aerodynamics, a mathematical quantity (dimensionless coefficient) equal to the total lift divided by the dynamic pressure and the reference area.

$$C_L = \frac{L}{qS}$$

where C_L is the coefficient of lift, L is the lift, q is the dynamic pressure, and S is the projected area of the airfoil. The coefficient of lift is a function of the airfoil shape, and the angle of attack. For a given shape, the C_L varies with the angle of attack. For a rocket of fixed yaw and fixed proportions moving in a straight line, the coefficient of lift is independent of air density and diameter of the rocket. It does depend upon the shape of the rocket, but for low velocities C_L is fairly independent of the velocity. For small pitch angles (i.e., angles of attack), the coefficient is relatively constant.

COEFFICIENT OF MOMENT. In aerodynamics, a non-dimensional value similar to the coefficients of drag, lift and thrust, except that coefficients of moments must include a characteristic length as well as the area. For example, the chord is used for a pitching moment of an airfoil. The moments involved in the reaction of a body in air are called the **pitching, yawing and rolling moments** (C_M , C_N , and C_L respectively). For rockets the coefficient of moment is sometimes called the "coefficient of restoring moment." (See also **restoring moment**.)

COEFFICIENT OF RESTITUTION (COLLISION COEFFICIENT). In a two-body collision involving particles 1 and 2, moving in the same straight line, the coefficient of restitution is defined by

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

where $u_1 < u_2$ are the velocities with respect to a primary inertial system before collision and $v_2 < v_1$ are the corresponding velocities after collision. For a completely elastic collision $e = 1$. For an inelastic collision $e < 1$. (See **impact**.)

COEFFICIENT OF THRUST. (1) In aerodynamics, a mathematical quantity equal to the thrust divided by the product of the dynamic pressure and the reference area. $C_T = T/qS$. (2) In propulsion, the *coefficient of thrust* is a function of the thrust of the rocket motor, the chamber pressure and the area of the throat of the motor. Thus, $C_F = F/p_c A_t$, where F is the thrust, p_c is the chamber pressure, and A_t is the area of the throat. Also:

$$C_F = \left[\lambda \Gamma' \sqrt{\frac{2}{\gamma - 1}} \eta_i + \frac{A_e}{A^*} \left(\frac{p_e - p_o}{p_c} \right) \right]$$

for design conditions, $p_e = p_o$

$$\text{then } C_F = \lambda \Gamma' \sqrt{\frac{2}{\gamma - 1}} \eta_i = \frac{F}{p_c A^*}$$

C_F is a function of altitude.

COEFFICIENT OF VISCOSITY. A factor of proportionality establishing the exact relationship of the general statement that the shearing stress, τ , developed within a fluid, or between a fluid and a body, is inversely proportional to the slope of the velocity profile. That is:

$$\tau = \mu \frac{dv}{dy}$$

where v is the velocity of the fluid, and y is the distance measured across the flow (μ is the coefficient of viscosity).

COHERENT CARRIER. A basic system operating on the principle involved in any transponder system, i.e., interdependence of a transmitter and receiver, e.g., in the **Dovap** system, the missile is interrogated and after the carrier is received it is retransmitted at a definite multiple frequency for comparison.

COIL. One or more turns of conductor when wound as a definite unit of an electrical circuit. Thus the choke coil, or as it is sometimes called, the "impedance coil," has a number of turns of wire forming a coil used primarily for its reactance effect. The transformer is a unit of one or more coils used for transferring electrical energy by magnetic induction, usually with changes in voltage and current.

COLD DROP. The release of an air-launched test vehicle without motor ignition, (i.e., not a "hot drop").

COLD FRONT. The forward boundary surface of an advancing cold air mass that is underrunning and displacing a warmer air mass. The term is also used in other senses, as determined by the meanings of "front."

COLD ROOM. An environmental test chamber used to provide a low temperature area for evaluating equipment in this regime.

"COLD TEST" OF RESONANT SYSTEMS. A test of a microwave system with the tube in place, but in a nonoperative condition so that its electronic admittance is zero. The resonance frequency, loaded and unloaded Q , and the driving point admittance are quantities usually measured.

COLEOPTER. One of a series of aerodynamic designs worked out at Oise, France. These are combined powerplants and wings giving an aerodynamic propulsive duct. The annular wing design has the great advantage of requiring no banking for turns. The missiles *Ogre I*, *Lutin* and *Naine Bébé* use this design, which is sometimes called a "flying barrel."

COLLAPSE. The destruction of a target by crushing (impulsion) due to external pressure from a blast.

COLLECTOR. (1) In an electron tube, an electrode that collects electrons or ions that have completed their functions within the tube. (2) In a **transistor**, an electrode through which a primary flow of carriers leaves the interelectrode region.

COLLECTOR RING. (1) A circular conductor for conveying electrical current to a gun turret, permitting full rotation of the

turret without twisting the incoming cables. (2) A hollow ring used to collect exhaust gases, as in a **turbosupercharger**.

COLLIMATION. The process of adjusting an instrument or device so that its reference axis is aligned in a desired direction with a predetermined tolerance. Examples are (1) in optics, adjustment of the line of sight of an instrument until it is in correct position relative to the other parts of the instrument. (2) In gunnery, the process by which the optical sights of a gun are aligned with each other, and both made parallel to the gun tube. (3) The adjustment of the optical and electrical axes of a radar to parallel positions. This is necessary before orientation can take place.

COLLISION. (1) As used in physics, this term refers to any interaction between free particles, aggregates of particles, or rigid bodies in which they come near enough to exert a mutual influence, generally with exchange of energy. It does not necessarily imply actual contact. The process is always subject to conservation of momentum, and in an "elastic collision," also to conservation of energy. In the latter case, if the initial velocities are given, the velocities of the bodies after collision can be calculated by applying these two conservation principles. The subject is of special significance in atomic physics, where a collision is defined as a close approach of two or more photons, particles, atoms or nuclei during which an interchange occurs of charge, energy, momentum or other quantities. (2) Physical intercept of a target by a missile, as distinct from a **near-miss**.

COLLISION, ELASTIC. A collision during which no change occurs in the internal energy of the participating systems; or in the sum of their kinetic energies of translation. The total mechanical energy is conserved, hence the **coefficient of restitution** is unity. (See also **impact**.)

COLOR CODE. In many mechanical fields where equipment repair and maintenance is likely to be required, it is convenient to apply colors in varying combinations to critical parts, either for the purpose of matching parts which go together, or of indicating the quantity or quality of the function produced. For example, resistors and condensers are color

coded to indicate their electrical values. In aircraft systems, it is customary to mark plumbing lines according to a standard coloring system which assists in identifying the maze of conduit and fluid lines. With military equipment, it is found simpler to paint the same color on corresponding plugs and sockets of electrical equipment to insure rapid and correct connections.

COLOR INDEX. The human eye is more sensitive to red light than is the photographic plate, while the latter is the more sensitive to the green and blue regions of the **spectrum** than is the eye. Accordingly, if we have a blue and a red star of the same apparent brightness, or in other words, the same visual magnitude, the blue star will make a much stronger image on the photographic plate than will the red. Hence, the scale of magnitudes determined from a sequence of stars of different colors, when determined photographically, will be different from that determined visually. The difference between the photographic and visual magnitude of any given star is known as the color index of the star. The algebraic sign of the color index is determined from the relation: photographic magnitude — visual magnitude = color index.

Since the **spectral type** of a star is also a function of the color of the star, we should expect to find a definite relationship between color index and spectral type. The "zero point" of the scale of photographic magnitudes has been defined in such a manner that the color index is zero for an AO type star between 5.5 and 6.5 magnitudes. For the other spectral classes the values of the color index are approximately:

B	A	F	G	K	M
-0.24	0.00	+0.28	+0.56	+1.00	+1.35

In accordance with the theory of **black-body radiation**, the apparent color of a radiating gas should be a function of the temperature of the gas and color index may be used as an approximate method for the determination of the temperature of the stars.

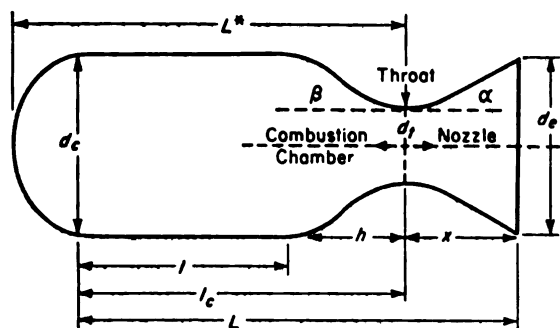
COLPITTS OSCILLATOR. **Oscillator, Colpitts.**

COLUMBIUM. Former name for the element **niobium**.

COMBUSTION. An exothermic chemical process usually producing high temperature

exhaust gases and light. Oxidation is generally involved. The process is slow compared to a chemical or nuclear explosion.

COMBUSTION CHAMBER. That portion of a thermal engine designed to contain chemical reactions yielding heat energy for conversion to usable work. In all thermal jet powerplants, energy is added to the air flow through the motor so that the exhaust velocity is higher than the intake velocity; thus a thrust is produced. The usual method of adding to the energy is the combustion of hydrocarbon fuels injected into the gas stream. In a rocket motor the combustion chamber is the source of all gases expelled, since no atmospheric air is required for combustion. (See figure.)



Rocket combustion chamber, throat and nozzle.

Any combustion chamber should have the following desirable characteristics: low weight, small frontal area, low pressure losses, high combustion efficiency, uniform temperature distribution at the outlet, stable operation, serviceability, accessibility, durability. (See **rocket motor**.)

COMBUSTION EFFICIENCY. The efficiency with which fuel is burned, expressed as the ratio of the actual energy released by the combustion to the potential energy of the fuel.

COMBUSTION, INCOMPLETE. Combustion in a rocket chamber is considered incomplete if not all oxidizer molecules are used up by reacting with fuel molecules. Fuel is present in excess for reasons of cooling, and of avoiding excessively high combustion temperatures.

Incomplete combustion results primarily from deficiencies in the injector system which may not atomize and mix the components effectively enough. The degree of combustion

is further influenced by the stay time of the gas in the chamber. The stay time is influenced by the reactivity of the propellant components and by the shape of the combustion chamber. The reactivity varies with size and mass of the molecules, and with the **energy of activation**. For instance, nitric acid requires a greater energy of activation than oxygen which is already present in pure form. Heating the nitric acid prior to injection, immediately results in an increase in performance at otherwise constant conditions. The reason is that the nitric acid vaporizes and mixes more readily, and is activated more easily and rapidly than if it were cold. Consequently, mixing and combustion are more complete, resulting in an increase in exhaust velocity.

The time required for complete reaction tends to be larger when heavy molecules are involved, for instance, carbon or metal molecules of low diffusivity, as compared to hydrogen. If the stay time for the given rate of reaction is too short, the gas must leave the chamber in a state of incomplete combustion.

Incomplete combustion tends to reduce the exhaust velocity below its theoretical value, since not all chemical energy of the fuel has been made available for accelerating the gas and producing thrust. Incomplete combustion further reduces temperature and pressure in the chamber. This, in turn, must increase the mass flow, since the cooler gas has higher density. As a result, the thrust is hardly affected by incomplete combustion, since the momentum thrust is the product of mass flow times exhaust velocity. Increased mass flow makes up for the lower exhaust velocity.

COMBUSTION INSTABILITY. An unsteady or irregular combustion of fuel, as may occur in a rocket engine.

COMBUSTION LIMIT. In solid propellant rockets, the lowest chamber pressure at which a given nozzle throat diameter will support regular burning of the motor without **chuffing**. It is a certain fixed value for each propellant and for each exhaust nozzle throat diameter. The combustion limit is also a function of the ambient temperature of the propellant charge. It is the lowest pressure at which stable combustion will occur.

COMBUSTION RESONANCE. **Chuffing.**

COMBUSTOR. The system comprising the flame-holder, igniter, combustion chamber, and injection system of a ramjet.

COMBUSTOR, CAN. A type of ramjet or turbojet engine combustor resembling a conically shaped, perforated "can." It usually has a separate assembly for the pilot stage.

COMET. (1) One of the bodies of the solar system following fixed orbits which travel in and out of the interplanetary space according to paths of varying eccentricity, some taking a few years to go around the sun and others hundreds of centuries. They are mostly long trails of gas extending behind a nucleus at the head of motion. (Usually there is in addition to the nucleus and tail, a hazy portion near or around the nucleus, called the "coma.") (2) Reportedly a U.S.S.R. solid propellant rocket series. Comet 1 was a missile of approximately 100-mile range; Comet 2 had a range of 650 miles and was also denoted as the M-102. Both rockets were reported to have an underwater launching capability. Comet 3 was a 100-mile range air-to-surface solid-propellant missile estimated to be 15 feet long and approximately 3 feet in diameter.

COMET ORBIT. Orbit, comet.

COMMAND. In computer work, one of a set of several signals (or groups of signals) which occurs as the result of an instruction; the commands initiate the individual steps which form the process of executing the instruction.

COMMAND CONTROL. The radio frequency link used for the purpose of sending commands to airborne missiles in order to direct their flight or in some way influence their performance. Command control links are usually VHF or UHF frequency modulated systems employing a number of subcarrier channels to allow a variety of missile functions to be controlled. Combinations of subcarriers can be transmitted to the missile to cause functions such as emergency safety cut-off of the motor, destruction of erratic missiles, disturbance maneuvers, actual flight path control or any of a variety of possible uses.

COMMAND CONTROL CENTER. A central station of an air defense system wherein information on enemy and friendly forces is collected and analyzed and appropriate com-

mands are issued. The SAGE system is a U.S. example.

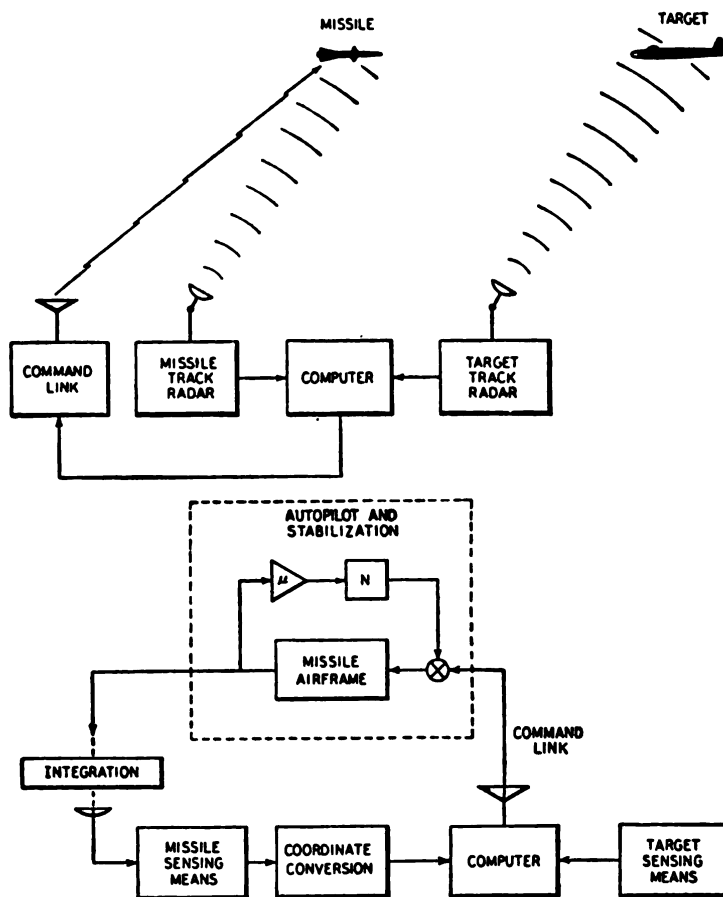
COMMAND DESTRUCT SIGNAL. A radio signal used intentionally to operate the destruction device carried in a missile.

COMMAND GUIDANCE. A form of missile guidance in which controlling signals are sent from the ground or another vehicle to effect flight control. Both attitude and path control may be from the ground, or attitude control may be managed by on-board gyro-sensings, and path control provided by the ground equipment. The missile may employ some additional form of terminal guidance, such as a homing system, when closing the target. The command guidance scheme was developed by the Germans during World War II and saw tactical use in the HS-293 and Fritz 1400 air-to-surface missiles.

COMMAND GUIDANCE SYSTEM. A system of missile control wherein intelligence transmitted to the missile from an outside source causes the missile to traverse a directed path in space. Missile command guidance systems in general require that the behavior of the missile (and of the target, if it is in motion) be monitored externally so that any deviation from a prescribed collision course may be computed, and the deviation communicated to the missile and interpreted by its control system so as to realign the missile flight path toward an intercept with the target. (See figure.) There are actually two systems of command guidance. The first uses a human controller who watches both the missile and the target, and flies the missile into the target from his visual estimation of their relative positions. The second method is the refined form in which calculations for the missile course are made on the ground by an automatic computer, and commands are transmitted to the missile. Two radar sets on the ground are used, one tracks the target and the other tracks the missile. Each of these radars feed position information into the ground computer.

COMMAND POST. The place from which a commander exercises his command function. Normally, each launch station and guidance station have a command post.

COMMUTATION. (1) The transmission of more than one signal over the same channel



Generalized command guidance system.

by means of sequential switching. The commutation process is used effectively in telemetering transmissions where one available channel may be used for a very large number of bits of information by means of high speed commutation. Commutation rates of 10-20 pieces of information per second, using either mechanical or electronic switching devices, are common. Commutation is not the same as **multiplexing**, but is a time-sharing process in which the information is not recorded continuously, but in discrete portions. Commutating telemetry information also requires additional instrumentation on the ground to decommutate or extract the functions from the composite. In some types of telemetering, there may be as many as 27 traces associated with one channel, each trace representing a separate function. The discrete intervals of the commutated trace are called "segments." Since the commutation process is fairly rapid, these segments are very short at average oscillograph paper speeds. (2) The process of converting alternating current to direct cur-

rent, by means of a rotating, sectoral or "split-ring" electrical contact that forms a part of the electrical generator. (See also **telemetering**.)

COMMUTATOR. (1) if A and B are two non-commutative operators, their commutator is

$$[A, B] = AB - BA.$$

According to quantum theory, if the commutator vanishes for two operators that represent dynamical variables, then the measurement of one of these variables does not interfere with that of the other. (2) A mechanical device for periodically changing the connections to a rotating member, or for interchanging the connections of two leads to an electric circuit. (See **commutation**.)

COMPARATOR. (1) An instrument for the accurate measurement of moderately small lengths or distances. The feature common to various forms is a reading microscope or telescope arranged to travel along a scale, its

axis remaining parallel to a fixed line. (2) A circuit which compares two signals and supplies an indication of agreement or disagreement. This circuit is also known as an "add-or-subtract" circuit.

COMPASS. Any device which establishes direction on the earth's surface.

COMPASS CALIBRATION. The process of compensating a magnetic compass and determining the amount of residual deviation after compensation. See **compass compensation**, **compass swinging**.

COMPASS COMPENSATION. The adjusting of a magnetic compass to correct for deviation, or, in the case of a gyro flux-gate compass, to calibrate the compass indicator. See **compass calibration**, **compass swinging**.

COMPASS COURSE. A course measured relative to compass north. It must be corrected for **compass error** and **magnetic variation** to get **true course**.

COMPASS DIRECTION. The direction indicated by a compass, relative to **compass north**.

COMPASS DEVIATION. The angle between **compass north** and magnetic north (i.e., the direction of the earth's north magnetic pole). Compass deviation is named east or west depending upon whether the north-seeking end of the compass is east or west of magnetic north. Deviation is the resultant of a large number of local magnetic fields, and these are subject to unpredictable changes.

COMPASS ERROR. (1) Any error in the indication of a compass, especially of a magnetic compass in an aircraft. (2) The angle between **compass north** and magnetic north.

COMPASS, FLUX-GATE. A compass operating on the principle of the magnetic modulator. Three cores with appropriate excitation and load windings are arranged to be perfectly balanced in the absence of external fields. The magnitude and phase of the unbalanced voltage on the load windings is proportional to the magnitude and direction of the external (earth) magnetic field, respectively. A **selsyn**, sensitive only to phase, is generally used as an indicator.

COMPASS HEADING. A heading measured relative to **compass north**.

COMPASS, INDUCTION. A compass which determines the direction of the earth's magnetic field with the aid of a rotating coil. Maximum induced voltage in the coil indicates that the rotational axis of the coil is perpendicular to the magnetic field.

COMPASS, MAGNETIC. Any device which indicates the direction of the horizontal component of the earth's magnetic field. The term usually refers to a magnetized needle which is free to rotate in a horizontal plane.

COMPASS NORTH. The direction indicated by the needle or other sensing element of a magnetic compass.

COMPASS, SATURABLE-REACTOR TYPE. Flux-gate magnetometer.

COMPASS SWINGING. A procedure whereby a compass is turned from one magnetic heading to another in a horizontal plane to determine its deviation.

COMPATIBILITY. (1) The nature of a color television system which permits substantially-normal, monochrome reception of the transmission by typical, unaltered monochrome receivers designed for standard monochrome. (2) That condition of two or more equipments or subsystems by which they can be made to function as an effective system.

COMPENSATED AMPLIFIER. A broad band amplifier in which the range is extended by choice of tubes and by slight resonant effects. They are used as video amplifiers.

COMPENSATING CIRCUIT. A circuit which functions to eliminate the effect of an undesired variable, often temperature, or to damp out noise.

COMPLETE ROUND. Round.

COMPLIANCE. In a mechanical system a measure of its responsiveness to a periodic force; it is that coefficient which, when multiplied by 2π times the frequency, is the reciprocal of the negative imaginary part of the *mechanical rectilinear impedance*. The unit is the *centimeter per dyne*. (See **compliance**, **mechanical**; **impedance**, **mechanical rectilinear**.)

COMPLIANCE, MECHANICAL. Compliance in a mechanical vibrating system is that coefficient which, when multiplied by 2π times the frequency, is the reciprocal of the negative imaginary part of the mechanical impedance. The unit is the *centimeter per dyne*. (See **compliance**.)

COMPLIANCE, ROTATIONAL. In a mechanical rotational system a measure of its responsiveness to periodic torque; it is that coefficient which, when multiplied by 2π times the frequency, is the reciprocal of the negative imaginary part of the *mechanical rotational impedance*. The unit is the *radian per centimeter per dyne*. (See **impedance, mechanical rotational**.)

COMPONENT. (1) One of a number of parts comprising a whole. In fabricated systems, a component usually performs a definite function, but depends upon other components to accomplish a given task. (E.g., gyroscope, accelerometer, amplifier, receiver.) In a missile system the usual components are **airframe, armament, propulsion, guidance, and control**. (2) In its general usage, one of the functionally definable parts of a machine circuit or other assembled aggregate, one of the ingredients of a mixture, or one of the distinct molecular or atomic species composing a mixture. In physical chemistry, one among the smallest number of chemical substances which need to be specified in order to reproduce a given chemical system. (3) The projection of a vector on a particular coordinate axis or along some specified direction. (4) The component of a tensor.

COMPONENT, CERTIFIED. **Certified component.**

COMPONENT PART. An item not normally subject to further disassembly. E.g., resistors, capacitors, tubes, potted or molded items, etc.

COMPONENT, QUALIFIED. **Qualified component.**

COMPOSITE. (OF A FORCE.) (1) Having or operating different kinds of equipment, as bomber air vehicles and ballistic missiles. (2) Made up of dissimilar elements as of two or more services.

COMPOSITE MISSILE. A multi-stage missile, or a missile assembled from parts of more than one missile.

COMPOSITE PROPELLANT. **Propellant, composite.**

COMPRESSED AIR. One of the important sources of power in missile control systems. High pressure air (3000 psi or higher) is frequently carried in air tanks aboard missiles. It is regulated down to lower pressures for operation of control surfaces, valve controls, and many other internal purposes. Commercial air is low pressure air of no particular quality as to dryness or oil content. Commercial air pressures would be 100-200 psi or lower. High pressure air must usually meet rigid specifications as to water vapor content and be oil-free as well as free of any solid particles of any great size. High pressure air can be delivered with special equipment up to 5000 psi. Hazards in connection with such pressures are severe, and usually stainless steel lines are employed for its distribution. Compressed air (also other gases) at low pressure is frequently used in missiles for fuel tank pressurization. Compressed air is safe for use on nitric acid or aniline as a tank pressurization force, but it cannot be used with aniline-cooled motors. When the air is blown through the cooling jacket at the end of the motor run, there is danger of an explosion of the aniline-air mixture in the cooling jacket from contact with the hot metal walls. Compressed air cannot be used for the pressurization of gasoline or nitromethane because of the explosion danger. It can be used for the pressurization of liquid oxygen and alcohol fuels. (See also **air, carbon dioxide, helium and nitrogen**.)

COMPRESSIBLE FLOW. A flow of air around a moving body, especially at transonic speeds, markedly changed in pressure and density from its free-air state.

COMPRESSIBILITY. (1) Relative change of volume per unit of pressure, $-dV/VdP$. In other words, the compressibility is the reciprocal of the bulk modulus. (2) In aerodynamics, relative change in volume of air due to the passage of a body through it. At speeds below 400 mph, compressibility effects are commonly disregarded because they are small as compared with the displacements of

air by the moving objects. At transonic and supersonic speeds compressibility effects assume importance in design. When the critical **Mach number** is exceeded, there is an almost simultaneous drop in the **lift coefficient**, an increase in the **drag coefficient**, and a tendency to pitch downward. These effects occur due to the formation of the supersonic **shock wave**. Some correlation has also been noted between Mach 1 and a tendency to roll. For velocities greater than the speed of sound, changes in pressure cause shock waves; these may cause increases in pressure and density, or on the contrary, may produce expansion waves which cause decreases in pressure and density. Compressibility effects are proportional to the velocity of the air flow. Compressibility causes sudden changes of flow pattern and loss of lift at the critical Mach number. Beyond the critical Mach number there is a range of speeds where the lift is increased; this is called the "Prandtl-Glauert effect." Note that it is not necessary that the vehicle's total velocity be at the critical Mach number; it is the local velocity which is critical. Shock wave formation can occur at Mach 0.75 (570 mph at sea level) over certain portions of an airfoil. (See **compressive flow**, **Glauert factor** and **Karman-Tsien relationship**.)

COMPRESSIBILITY BURBLE. A disturbed flow of air produced by, and aft of, a **shock wave**.

COMPRESSIBILITY EFFECT. An effect on an aircraft or missile resulting from compressibility as the flow of air passes through the **shock wave**.

COMPRESSIBILITY MODULUS. The relative change in volume per unit change of pressure; in other words, the reciprocal of the bulk modulus.

COMPRESSIBILITY NUMBER. The ratio of the velocity of a body to the speed of sound. It is the same as **Mach number**.

COMPRESSION. (1) In general usage, compression is descriptive of the decrease of volume of a compressible substance (solid, liquid or gaseous) due to the application of pressure. The compression of gas may be adiabatic, isothermal, or, more commonly, neither of these two, and in that case, have a pressure increase intermediate between those for each of the

two. (2) In structural engineering, compression is the stress which causes the fibers of a member to shorten. (3) In electronics, compression is the ratio of the small-signal power gain g_0 of a device to the power gain g_1 at some higher power level. Expressed in decibels:

$$\text{Compression} = 10 \log_{10} \frac{g_0}{g_1}$$

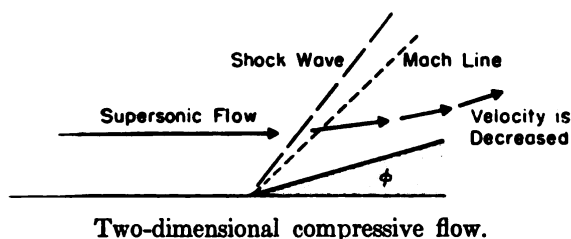
(4) In television, compression is the reduction in gain at one level of a picture signal with respect to the gain at another level of the same signal. The gain referred to in the definition is for a signal amplitude small in comparison with the total peak-to-peak, picture signal involved. A quantitative evaluation of this effect can be obtained by a measurement of differential gain.

COMPRESSION RATIO. Ratio of expansion.

COMPRESSION WAVE. (1) A wave in an elastic medium which causes an element of the medium to change its volume without undergoing rotation. (More broadly, a wave whose intensity field has zero curl.) (2) A discontinuity in the stream line pattern of moving fluid as it passes around a body. As the flow velocity over the body increases this discontinuity becomes more and more abrupt, eventually becoming a **shock wave** at supersonic velocities. Within a compression wave, the flow velocity is decreased, density and pressure are increased adiabatically. (3) A wave in a fluid flow across which the compression is slight or infinitesimal.

COMPRESSIVE FLOW. Flow which results in compression, e.g., the flow of a fluid against a surface inclined to the streamlines. At lower velocities, the compressional effect is small, but it increases rapidly with fluid velocity. When the velocity is supersonic, a shock wave originates from the point at which the direction changes. This shock wave will be inclined at an angle proportional to the **Mach number** and the form of the surface. The study of compressive flow conditions is important in supersonic aerodynamics. (See figure on Page 143.)

COMPRESSOR. A mechanical device for increasing fluid pressure. Classified by the fluid flow pattern, compressors are *axial* or



centrifugal. The most efficient compressors are rotary types with vanes or other arrangements of the rotary parts made to collect and accelerate the working fluid. Centrifugal compressors (or pumps if the working fluid is a liquid) are the simplest types. Axial compressors are used in jet aircraft since they can impart greater velocities.

COMPRESSOR, VOLUME. In amplitude modulation systems of radio communication, the amount of intelligence volume which can be modulated upon the carrier is limited to an amount which will give 100% modulation. Since the percentage of modulation depends directly upon the volume of the sound, it follows that, in order not to exceed the allowable modulation on very loud sounds, the percentage on most sounds will be rather low. Since the maximum use is made of the power and a higher signal to noise ratio is obtained for high degrees of modulation, it is very desirable to keep the level of modulation as high as possible. To do this the volume range of the original sound is compressed into a much smaller range. Thus, while a symphony orchestra may have a volume range of 100-110 db, the range is compressed to about 40 db for broadcast purposes. In recordings the maximum volume which may be recorded is limited by the thickness of the groove walls so the volume range is reduced here also. An **expander** may be used in the reproducing system of the radio circuit or the phonograph to restore the original range.

COMPUTED ALTITUDE. The angular altitude of a celestial body above the celestial horizon from an assumed position, computed to facilitate the finding of a **line of position**. (I.e., an assumed position locus for a given time.)

COMPUTER. (1) A device which can accept information and supply information, and in which the supplied output information is derived from the accepted input information

by means of a process of logic, i.e., any systematic process of derivation which is demonstrably free from self-contradiction. (2) A missile computer takes missile position and velocity information and provides a simultaneous solution to the equations of motion, yielding predictions as to what changes in linear displacement, velocity, or acceleration the missile must be effected for target interception. Military considerations for computers are: precision, response time, size, weight, serviceability, cost, and accuracy. For permanent ground computers for data processing, capacity, flexibility, and reliability are probably more important considerations.

COMPUTER, ANALOG. A computer in which quantities and relationship are represented by continuously variable physical quantities (e.g., voltages) such that approximate solutions can be obtained readily.

COMPUTER COMPONENTS. Computer components are designed to perform certain mathematical operations. For example, there are: adders (differential gears), integrators (wheel and disc), differentiators (centrifugal type or electronic circuits), multipliers (gear ratio, rack-and-gear, proportional triangles, serial adders), resolvers (gridded discs with centrally pivoted reading arms for component resolution as for wind direction), function generators (cams or potentiometers). Computer components may also do operations such as: programming, digitalizing, conversion from digital to analog (form transformation), operational control, timing pulse generation, storage, gating, serial binary subtraction or addition, parallel addition or subtraction, multiplication by register shifting, function generation by series approximations, division by trial addition and subtraction, calculus operations by numerical addition and subtraction, assertion, negation, etc.

COMPUTER, DIGITAL. A computer in which quantities are represented in numerical (as distinct from analog) form; generally designed to solve complex mathematical problems by iterative use of the fundamental processes of addition, subtraction, multiplication, and division.

COMPUTER EQUIPMENT. Because of its complexity, computer equipment is usually produced under contract by specially qualified

manufacturers. The larger computer manufacturers often provide their equipment on lease (including the provision of maintenance service). The following items are examples of computer equipment: card punch machines, punched-card sorters, alphabetical collators, electronic statistical machines (they automatically reject and isolate data, and state improbable situations), electronic calculating punches, card-programmed electronic calculators.

COMPUTER FUNCTIONS. Discussed under **computer components**.

COMPUTER INSTRUMENTATION. In a digital computer, the generation of logical statements requires signals representing merely "True" or "False" conditions. "True" would be represented by a positive pulse on the assertion lead, and "False" by a negative pulse on the negation lead. The generation of the desired logical statements is made by appropriate connections between these two inputs. Complex logical manipulations and numerical computations can be built up in computing machines from these two inputs. The "True" or "False" condition can be represented by various physical means, a light on or off, a relay open or closed, a vacuum tube conducting or non-conducting, a voltage pulse present or absent. The logical statements beyond "True" or "False" are instrumented by appropriate connections between the two inputs. Such logical statements are "NOT," "AND," "OR," "EXCEPT," "EXCLUSIVE OR." For example, "AND" is instrumented by a "gate" or coincidence detector which requires all inputs to be "True" for the output to be "True." If there is one "False" input then the output is "False." "OR" is produced by means of a "buffer" or system of direct connection between several variables so that if one or more of the variables is "True," "True" will appear at the output of the buffer. Schematically, the computer logic circuits would operate as follows:

"AND"	C = 1 when A = 1 <i>and</i> B = 1
"OR"	C = 1 when A <i>or</i> B = 1
"NOT"	C = 1 when A <i>or</i> B = 1 <i>or</i> A <i>and</i> B = 1
"EXCEPT"	C = 1 when A = 1, <i>ex-</i> <i>cept</i> when B = 1

"EXCLUSIVE OR" C = 1 when A = 1, or
B = 1, but not both
at the same time

"AND," "OR" and "NOT" are the basic circuits and "EXCEPT," "EXCLUSIVE OR" and others are made from combinations of the basic circuits. For example: 2 NOT + 2 AND + 1 OR = EXCLUSIVE OR.

COMPUTER, SPHERICAL-TRIGONOMETRIC. A computer capable of converting distance traveled into corresponding changes in latitude and longitude for the particular latitude of the missile.

COMPUTER STORAGE. The basic requirement of any computing system is that it can "remember" a large number of data items which are to be manipulated in the computations. The general requirements for computer storage facilities are: (1) large capacity, (2) ability to store information indefinitely, (3) ability to accept information rapidly, (4) ability to deliver information rapidly, (5) adaptability to reliable operation (light weight, simple, small space). Types of storage devices are: (1) **Delay lines** (electrical, acoustic, time delay). These all have the disadvantage of "volatility" (i.e., when the power is off the information is lost). (2) **Magnetic drums** (a drum 10 inches in diameter revolving at 7000 rpm can handle 2000 bits of information per square inch. Such information is non-volatile and a total of 125,000 bits of information per second can be handled; access to any single piece can be obtained within 50 milliseconds). (3) **Cathode ray tubes**. (4) **Magnetic tapes**, or even punched cards or tape may be used as memory units, but these all involve long access times for the extraction of information.

ConAC. Continental Air Command.

ConAD. Continental Air Defense.

CONCENTRATION. Relative amount of a particular constituent in a mixture.

CONDENSATION TRAIL (CONTRAIL). A visible trail of small water droplets of ice crystals formed under certain conditions in the wake of an aircraft, rocket or missile.

CONDOR. A radio-navigation system utilizing a method of transmission and equip-

ment by means of which a navigator can find both range and bearing relative to the transmitting station.

CONDUCTION. The transmission of energy (heat, sound, electricity) by means of a medium without movement of the medium itself, as distinguished from convection, in which such movement occurs, or from radiation in which the energy quanta pass through the medium and so the transmission does not occur by means of the medium.

CONDUCTION, ELECTRIC. The conduction of electricity in material substances is of two general kinds. (1) A migration of ionized (and hence electrified) atoms or molecules, as in **ionized gases** and **electrolytes**. (2) A process in which the atoms are in the main stationary, as in metals.

The electric conductivity of solids has an almost unbelievable range. For silver and sulfur (the best and the poorest among elements), the ratio is something like 1000 billions of billions to 1. Their resistivity is, of course, in the inverse ratio. Metals, as a class, aside from being almost immeasurably better conductors, differ in several respects in their conduction from non-metals. For example, the conductivity of pure metals consistently decreases with rising temperature, while the non-metallic solids, including carbon, generally have maximum conductivity at one or more temperatures. Selenium has most extraordinary properties. Some metals exhibit superconductivity near the absolute zero of temperature. The alloying of metals, and even the admixture of small quantities of impurities, often profoundly affects the conductivity. Thus "constantan," an alloy of copper and nickel, shows almost no change of conductivity with temperature.

CONDUCTION, THERMAL. The processes of heat transport through a substance, excluding heat transfer due to mass flow in the substance. The heat flowing per unit time through a sample with cross-section A and length l under a temperature difference ΔT is given as $Q = KA\Delta T/l$, where K is a material constant called the thermal conductivity of the substance. More generally, $Q/A = -KdT/dl$, where the negative sign indicates that the heat flow is in the opposite direction to the temperature gradient, dT/dl .

CONDUCTOR. A material which, when placed between terminals having a difference of **electrical potential**, will readily permit the passage of an electric current is an electrical conductor. Different materials have different degrees of conductivity, and their effectiveness in this respect is computed as the conductivity.

CONDUIT. A container or protective channel (e.g., pipe) containing one or more electrical cables. Conduit may be either iron pipe conduit, tile conduit, flexible conduit, armored conduit, etc. If conduit contains one duct it is called "single-duct conduit," or if more than one cable duct, "multiple-duct conduit."

CONE OF SILENCE. Radio range.

CONELRAD. A short title determined as a convenience in referring to a Department of Defense plan (24 December 1952) for the *CON*trol of *EL*ectromagnetic *RAD*iations in the event of enemy attack. At the first indication of enemy weapons approaching the U.S., all television stations and all regular radio stations, both AM and FM will go off the air. The CONELRAD stations, 640 or 1240 on the AM dial will operate for emergency communications. The physical location of these stations will be concealed by technical means.

CONFIDENCE INTERVAL. A statistical term establishing the difference between the upper and lower **confidence limits**.

CONFIDENCE COEFFICIENT. Confidence level.

CONFIDENCE LEVEL (CONFIDENCE COEFFICIENT). The percentage of statements, tests, etc., expected to be correct. The certainty with which data from a small group applies to a specific confidence interval. By using appropriate data and a selected confidence level (i.e., at a 95% confidence level, the conclusions drawn will be in error only one time in twenty—on the average).

CONFIDENCE LIMITS. The computed upper and lower limits of the desired value of a physical quantity.

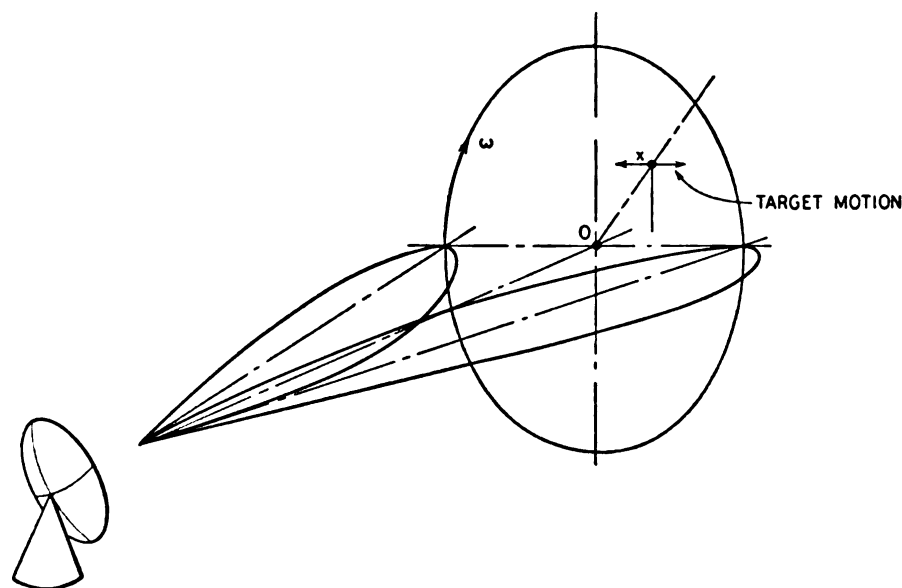
CONFIGURATION. The relative arrangement and distribution of parts in a structure,

generally referring to the outer appearance. The configuration of an object is its general outline, and arrangement of parts and components without regard to scale. For example, a model and a full-sized missile could have the same configuration, or "shape."

CONFORMAL MAPPING. A method of representing diagrammatically the performance of a **servo system**. Consider first the loop transfer function $Y_0(s)$, where in general s is a complex number of the form $s = \alpha + j\omega$. Corresponding to each value of s there is particular value of $Y_0(s)$. This can be shown by showing the value of s as a point in a complex plane called the s plane, and the corresponding value of $Y_0(s)$ as a point on another complex plane, called Y_0 plane. Corresponding to a contour in the s plane there is a contour in the Y_0 plane. The shape of the letter depends on the function $Y_0(s)$ and hence on the parameters of the servo it repre-

CONICAL FLOW THEORY. A theory based upon the assumption that flow of fluid around a cone-shaped body has constant pressure, density, velocity and temperature along any radius starting at the apex.

CONICAL SCANNING. A radar scanning system wherein a point on the axis of a **radar beam** describes a circle at the base of a cone, and the axis is the generatrix of the cone. The purpose of conical scanning is to cause a target to yield a different return if it is in the center of the cone, than if it is removed therefrom. By means of this difference in the returned signal, the direction of a target may be determined by realigning the cone upon it. Such a type of scanning can be achieved with a fixed-plane polarization and with the antenna feed nutated around the axis of a paraboloid reflector. See figures for illustration of conical scan and the corresponding signal returns.



Conical scanning radar.

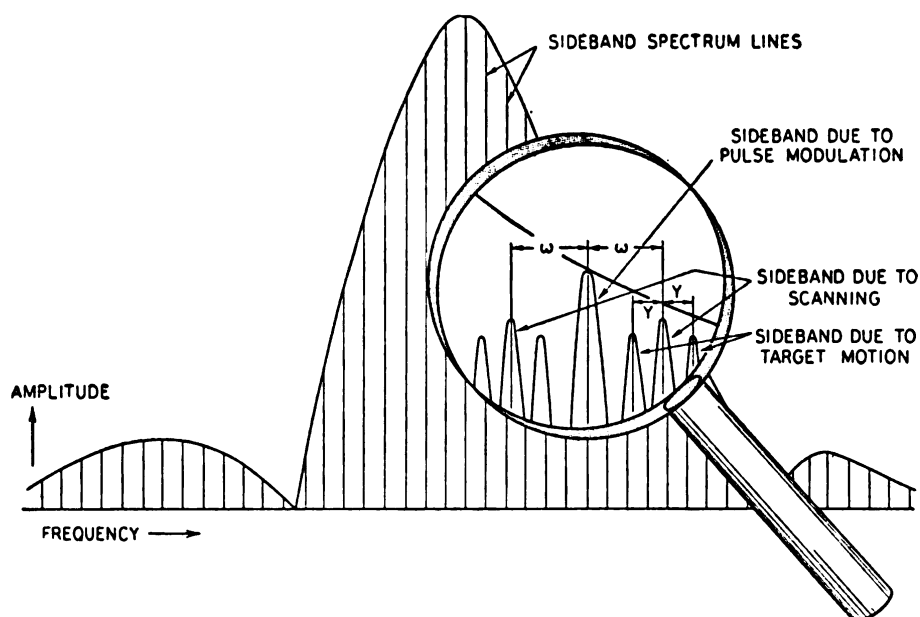
sents. Thus, if the s plane is divided into a net of lines of constant α and constant ω , parallel to the axes, there is a corresponding pattern of lines in the Y_0 plane.

CONFORMAL PROJECTION. A mapping system wherein a surface in a given coordinate system is mapped or transformed into an alternate reference system without change in the angular relationship between any two points.

CONIC ORBIT. Orbit, conic.

CONNECTOR. A fitting used to join electrical wires or cables, especially where service conditions require effective joints. An example is electrical equipment subject to high vibrations or requiring low-resistance junctions, especially where frequent disconnections must be made. Connectors come in a variety of sizes, physical structures and electrical ratings.

CONSOL. A long-range, low-frequency, radio-navigation system using a rotating pattern of dots and dashes and equisignal zones.



Conical scanning radar spectrum.

Bearing to the transmitter is determined by counting the dots and dashes on each side of an equisignal zone and by reference to a special chart.

CONSOLE. A basic instrument control panel usually mounted on a large tablelike piece of equipment with a slanting top, and used as a "go-no-go" control for the launching of a missile and/or its subsequent flight.

CONSTANT-BEARING COURSE. A missile trajectory wherein the line of sight from the missile to the target maintains a constant direction in space.

CONSTANT-BEARING NAVIGATION. Navigation, constant bearing.

CONSTANT M CONTROL. A method of controlling a missile power plant in which the **Mach number** M rather than the velocity is held constant. To keep M constant, it is sufficient to measure ram air pressure and static air pressure, and to provide a solution to the equation:

$$\frac{P_{02}}{P_1} = 1.2M^2 \left(\frac{7.2M_1^2}{M_1^2 - 1} \right)^{2.5} \quad \text{for air}$$

Constant M is used because of the ease of measurements required for control and because most other parameters are a function of M rather than velocity. It follows that constant M control does not necessarily yield constant air speed. (See **Mach meter**.)

CONSTANT OF GRAVITATION. The acceleration that results from the attraction of a unit of mass at unit distance, which has a value of $6.670 \times 10^{-8} \pm .005$ dyne cm^2/gm^2 .

CONSTANT AIR SPEED CONTROL. A method of controlling a missile power plant to maintain constant air speed rather than constant **Mach number**. It is necessary and sufficient to measure raw air pressure, static pressure and air temperature to establish the proper thrust control. Constant air speed control is used to avoid the need for a present position indicator; air speed and time being used in computing range.

CONSTELLATIONS. In astronomy this term is used to designate certain groupings of the **stars**. From earliest recorded history we find that the larger star groups (constellations), the smaller groups (asterisms such as the **Pleiades**), and the individual stars have received names symbolizing meteorological, religious, or mythological beliefs. The idea that the constellation names and myths are of Greek origin has been quite completely disproved. It seems highly probable that they are of Semitic or Pre-Semitic origin and that they found their way into Greece through contact with the Phoenicians (sailors who used the stars constantly in their profession).

The oldest record of actual constellation listing is found in the Creation Legend in about 650 B.C. This Legend was recorded on

LIST OF CONSTELLATIONS

North of the Ecliptic

- * **Andromeda**—Fig. III, 1, N
- * **Aquila**—Fig. II, 3, C
- * **Auriga**
- * **Bootes**—Fig. II, 1, F
 - Camelopardalis
 - Canes Venatici
- * **Cassiopeia**—Fig. I, I
- * **Cepheus**—Fig. I, IV
 - Coma Berenices
- * **Corona Borealis**
- * **Cygnus**—Fig. II, 1, C
- * **Delphinus**
- * **Draco**
- * **Equuleus**

Zodiacal

- * **Aquarius**—Fig. II, 3, B
- * **Aries**—Fig. III, 2, N
- * **Cancer**—Fig. III, 2, J
- * **Capricornus**—Fig. II, 4, B
- * **Gemini**—Fig. III, 2, K
- * **Leo**—Fig. III, 2, H

South of the Ecliptic

- Antilia
- Apus
- * **Ara**
 - Caelum
- * **Canis Major**—Fig. III, 4, K
- * **Canis Minor**
- Carina
- * **Centaurus**—Fig. II, 5, F
- * **Cetus**
 - Chamaeleon
 - Circinus
 - Columba
- * **Corona Australis**
- * **Corvus**—Fig. II, 4, G
- * **Crater**
- * **Crux**
 - Dorado
- * **Eridanus**
 - Fornax
 - Grus
 - Horologium
- * **Hydra**
 - Hydrus
 - Indus

- * **Hercules**—Fig. II, 2, E
 - Lacerta
 - Leo Minor
 - Lynx
- * **Lyra**—Fig. II, 1, D
- * **Ophiuchus**
- * **Pegasus**
- * **Perseus**—Fig. III, 1, M
 - Sagitta
 - Serpens
- * **Triangulum**
- * **Ursa Major**—Fig. I, II
- * **Ursa Minor**—Fig. I, III
 - Vulpecula

- * **Libra**—Fig. II, 4, E
- * **Pisces**—Fig. III, 3, A
- * **Sagittarius**—Fig. II, 4, D
- * **Scorpius**—Fig. II, 5, E
- * **Taurus**—Fig. III, 2, M
- * **Virgo**—Fig. II, 3, F

- * **Lepus**
- * **Lupus**
 - Mensa
 - Microscopium
 - Monoceros
 - Musca
 - Norma
 - Octans
- * **Orion**—Fig. III, 3, K
 - Pavo
 - Phoenix
 - Pictor
- * **Piscis Austrinus**
 - Puppis
 - Pyxis
 - Reticulum
 - Sculptor
 - Scutum
 - Sextans
 - Telescopium
 - Triangulum Australe
 - Tucana
 - Vela
 - Volans

Cuneiform from even earlier records. From this time onwards frequent references to the constellation legends are to be found both in

poetical and historical writings. The basis for the modern constellation division is to be found in the list of 48 constellations published by

Ptolemy in about 150 A.D. This list of Ptolemy is based upon the writings of his predecessors, notably Hipparchus.

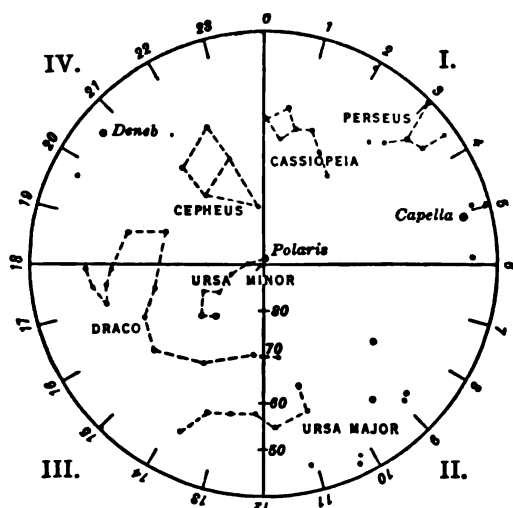


Fig. I. Circumpolar stars.

The boundaries of Ptolemy's constellations were very indefinite and many visible stars were left out entirely. Furthermore, his list only covered that portion of the heavens visi-

of defining the constellation boundaries in the hands of a special committee and in 1930 the final list was published.

Several attempts have been made to supplant the ancient mythological names with more modern ones (e.g., the *Coelum Stellatum Christianum* of Julius Schiller in 1627 in which we find the ancient names replaced by names of various Church dignitaries) but none of the attempts have been successful.

The list on Page 148 contains the names of all of the constellations now used; those in bold-face type are treated elsewhere in this volume in special articles, and those marked with an asterisk are the original constellations of Ptolemy. The most important and easily recognized constellations will be found on the star maps, accompanying this entry, and the numbers (e.g., Aries—Fig. III, 2, N) refer to the particular map and location on that map where the constellation will be found.

CONSTRAINT. (1) Any particle or collection of particles is said to be subject to "constraint" if the number of **degrees of freedom** is less than $3N$, where N is the number of particles. (2) Specifically that property

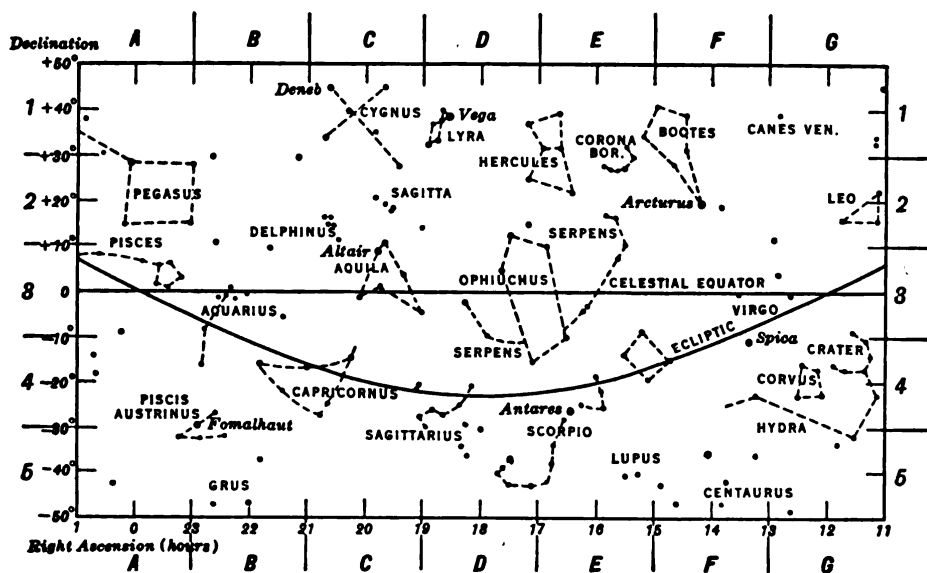


Fig. II. Equatorial stars.

ble from the southern Mediterranean regions. In the 1800 years since Ptolemy's time the list has been added to and the boundaries defined until at present all stars are included in some one of the constellations. The International Astronomical Union placed the matter

which distinguishes a mechanism from other mechanical linkages. A mechanism has constrained motion in that a motion of one part is followed by a predetermined motion of the remainder of the mechanism. To determine whether a mechanical linkage is a mechanism

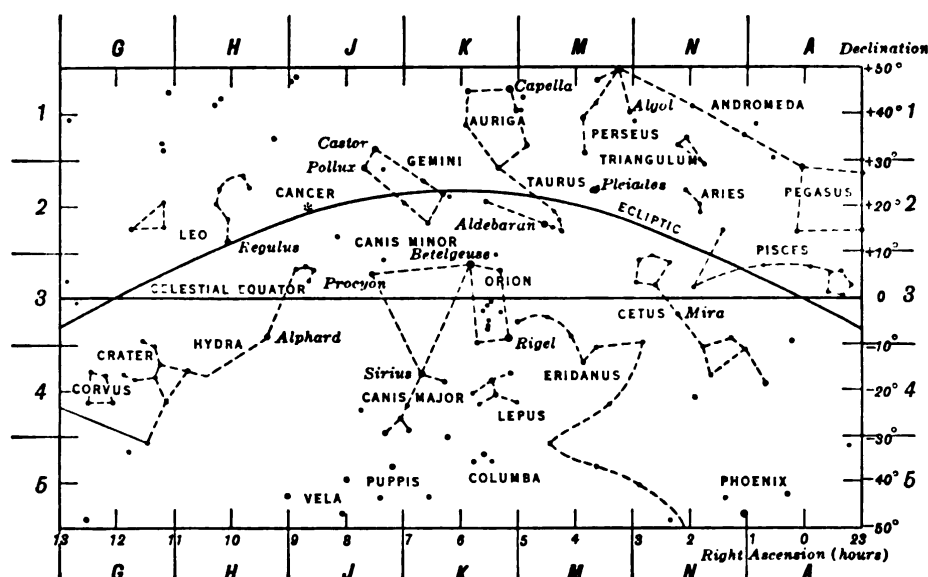


Fig. III. Equatorial stars.

or not, Klein advocates applying the criterion of constraint, which he writes as follows:

$$J = \frac{3N - 4 + \gamma - P}{2}$$

in which J is the number of joints in the mechanism, N is the number of links in the mechanism, γ is the number of independent prismatic chains, that is, those whose joints are of the sliding type, P is the number of point or line type of contact joints in the mechanism. When this equation yields an identity, the mechanism is said to be "constrained for all dimensions."

CONSTRUCTOR. The exit portion of the combustion chamber in some designs of ram-jets, where there is a narrowing of the tube at the exhaust.

CONSUMER'S RISK. The probability or risk of accepting a lot, for a given lot quality or process quality, whichever is applicable. The term is usually applied only to quality values that are relatively poor.

CONTACT FUZE. A device which initiates warhead detonation after some interval of time following impact with a target surface.

CONTAMINATION. The deposit of radioactive materials, such as fission fragments or radiological warfare agents, on any objective or surface, thereby making it hazardous.

CONTINENTAL AIR DEFENSE. A coordinated defense of the continental United States against air or missile attack. The defense is coordinated as among the ground, sea, and air forces, and civil defense authorities.

CONTINUITY, EQUATION OF. In one form of the equation of continuity, the principle of the conservation of matter is stated in the following form: The rate of increase of the particles in an element of volume is equal to the net inward flow across the surfaces of the element. In mathematical terms

$$\frac{d\rho}{dt} + \text{div } \mathbf{j} = 0$$

where ρ is the density of the medium and \mathbf{j} is the mass current density vector. With proper changes in the meaning of ρ and \mathbf{j} , the equation expresses the conservation of other quantities, such as charge, energy, etc.

CONTINUOUS-DUTY RATING. Rating, continuous-duty.

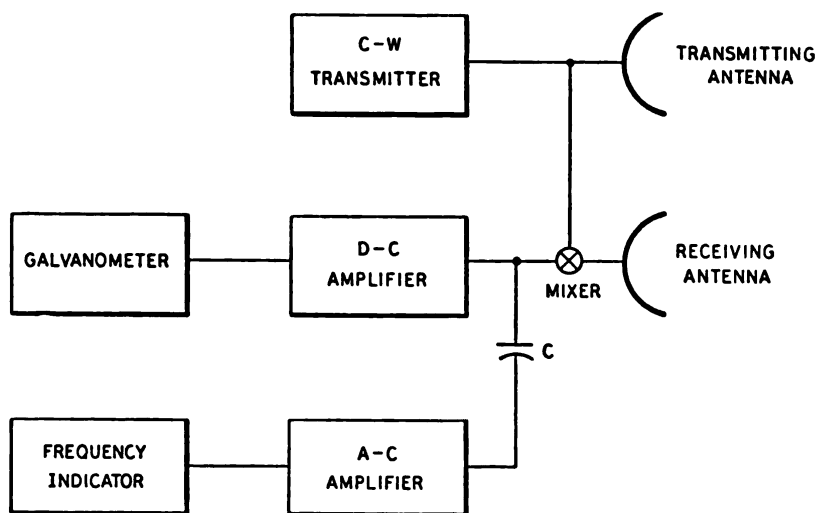
CONTINUOUS WAVE. (CW) A radio or radar wave that maintains a constant amplitude and a constant frequency under steady-state conditions, that is, without interruption.

CONTINUOUS WAVE (CW) RADAR. A radar system operating on continuous waves. Since both transmitter and receiver are continuously in operation, they require separate antennas unless there is relative motion be-

tween radar and target; a limitation of the system for ground-to-ground use. (See figure.) Waves reflected from stationary objects cannot be distinguished in timing (since they are continuous) or in frequency, from the transmitted waves. On the other hand,

CONTRAORBITAL DIRECTION. The direction opposite to the direction of travel of the body is an orbit.

CONTRAST. (1) In radar, the contrast of an echo is the degree of difference of its



C-W Doppler radar.

waves reflected from moving objects undergo a frequency shift (**Doppler effect**) corresponding to the line-of-sight speed of the object. (See **velocimeter**.)

This limitation can be overcome by modulating the transmitted wave (e.g., frequency modulation) but the radar is then not strictly of the CW type.

CONTOUR. A line joining points of equal value. Thus, on maps, contours join points of equal elevation. In data reduction applications, an (error) contour is a line joining points of equal instrument errors. Such lines are plotted on a diagram to show error regions.

CONTRACTION RATIO. The ratio of the uncontracted cross-sectional area of a duct or passage to the contracted cross-sectional area, such as the ratio of the uncontracted cross-sectional area of a wind tunnel to the cross-sectional area of the throat. An example is the ratio of the combustion chamber area to the throat area of a rocket motor.

CONTRAIL. Condensation trail.

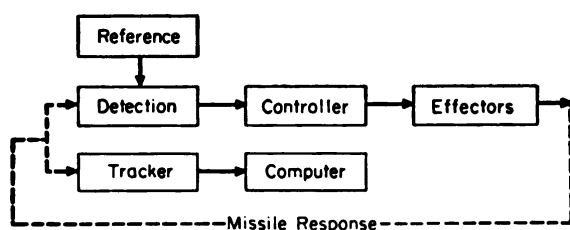
CONTRA-INJECTION. In a jet engine the injection of fuel into the air stream in a direction opposite to the flow of air.

pip shown on the oscilloscope compared to background field. (2) In photography, the slope of the curve plotted between density and the log of exposure (see **H and D curve**). (3) In television, the ratio between the maximum and minimum brightness values in a picture. (4) In psychophysics, the change in the response to a stimulus as a result of the proximity in space or time of other stimuli. In general, the response to a stimulus of given physical intensity is reduced if neighboring stimuli have greater intensities, and *vice versa*.

CONTRAVES. A tracking camera used in photogrammetric applications. It is normally used in 2-3 camera synchronous systems. Two operators are required for each instrument, one tracking in azimuth and the other in elevation. One model of the Contraves camera has a focal length of 1500 cm and can operate at frame rates up to 30 per second. Power-aided tracking is used for both azimuth and elevation. Timing correlation is accomplished by matching frame numbers. Film must be read by a special Contraves reader. The Contraves equipment is manufactured by the Swiss company, Oerlikon.

CONTROL. (1) A system or device which exerts a restraining, governing or directing in-

fluence. (2) An experiment or test done to confirm or to rule out error in experimental observations. (3) The process of stabilizing a missile with respect to disturbances (such as gusts of wind), while simultaneously furnishing satisfactory responses to guidance signals. Control is usually divided into the two general areas of attitude control and path control. Control can be directed either internally (i.e., within the missile) or externally, but is executed (by definition) only within the missile. Control problems involve the operation of aerodynamic surfaces, jet vanes, air vanes, gas jets, or other force-developing devices to maneuver the missile. It also includes all the intelligence information required to correct the spatial position of the missile, its power devices and its servo-mechanisms, as well as all the physical, electrical, pneumatic, hydraulic, or other interconnections necessary to unite all the controlling components into a coordinated whole. Control, in essence, is the steering of the missile. A block diagram showing the control functions of a missile is shown below:



Control functions of a missile.

Missile response is the feedback loop which monitors the performance of the missile under the control commands. **Guidance** comprises the functions by which the missile is directed to the target; control involves the use of the guidance information to steer the missile to its target according to the guidance plan. (See also **servomechanism**.)

CONTROL, BANG-BANG. A control method wherein the corrective control applied to the missile is always applied to the full extent of servo motion.

CONTROL CENTER. The facility from which command is exercised over a group of missile launch complexes.

CONTROL CHARACTERISTIC. (1) Of a magnetic amplifier, a curve of the output

quantity versus control quantity under specified conditions, both expressed in suitable units. (2) Of a gas tube, a curve of the critical grid voltage versus anode voltage.

CONTROL CIRCUIT. (1) Of a magnetic amplifier, the control windings and the voltage sources and impedances which are connected to them, and which together determine the current in the control windings. (2) The circuits of a digital computer which effect the carrying out of instructions in proper sequence, the interpretation of each instruction, and the application of the proper commands to the arithmetic element and other circuits in accordance with this interpretation.

CONTROL GRID. Grid, control.

CONTROL HYSTERESIS. A control characteristic which is double-valued. This may be encountered in amplifiers with excessive amounts of positive feedback, or in some forms of magnetic amplifiers with inductive load. Sometimes called "snap action."

CONTROL, LOCAL. A system or method of radio-transmitter control whereby the control functions are performed directly at the transmitter.

CONTROL, PLANE. Control in which the action to correct an error is made proportional to that error.

CONTROL POINT. The value of the controlled variable which, at any instant, an automatic controller endeavors to maintain.

CONTROL, PROPORTIONAL. Control in which the corrective control applied to the missile is made proportional to the error signal.

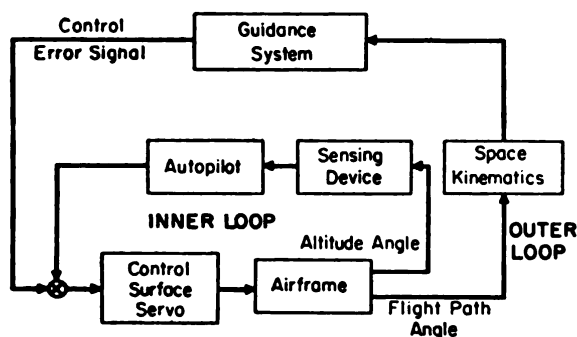
CONTROL SURFACE. A movable airfoil or surface, such as an aileron, elevator, rudder-vator, flap, trim tab, etc., used to control the attitude or motion of an aircraft, rocket, missile, or other body and to guide it through the air; specifically, one of the surfaces used principally for control, as an elevator, rudder, elevon, etc.

CONTROL-SURFACE AREA. The area within the outline of a control surface exclusive of any area on that side of the hinge axis nearer the fixed surface to which the control

surface is attached. The area of any tabs set into the control surface is normally included, but the area of any tabs lying outside the control surface proper is not included.

CONTROL, SURVEY. Survey.

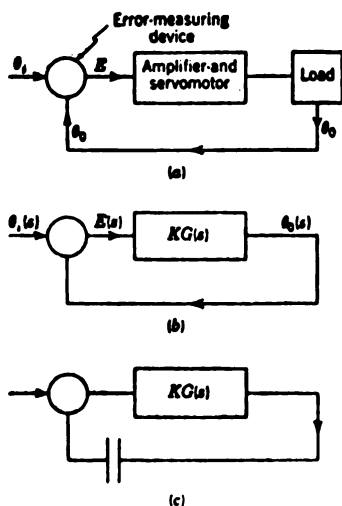
CONTROL SYSTEM. (1) A coordinated group of components designed to exert a directing influence on other components. (2) The system for properly maneuvering a missile in response to guidance intelligence; these usually include an autopilot, servos and control surfaces or jets. (See figure.) (3) A



Control system (inner loop) operating in a guided missile.

group of control consoles, housed in the block-house, that monitor and launch the missile utilizing radio and electronic control devices. (See **control system, automatic**; **control system, flight**.)

CONTROL SYSTEM, AUTOMATIC. Any operable combination of one or more **automatic controls** connected in closed loops with one or more processes. (See figure.)



A control system loop, closed and opened.

CONTROL SYSTEM, FLIGHT. The flight control system has three functions. The primary function is to maintain missile stability about the pitch, roll, and yaw axes. The second function is to receive command signals from the guidance system and convert these signals into mechanical movements of the servos to change the missile course. The third function is to turn (pitch) the missile onto the proper target heading in the early moments of flight.

CONTROL VANE. A movable vane used for control, especially a movable **air vane** or **jet vane** on a rocket, used to control flight direction.

CONTROLLABILITY. The ability of a missile or aircraft satisfactorily to control its maneuvers in response to guidance intelligence.

CONTROLLED TEMPERATURE CABINET. An environmental test facility with **automatic control** accessories for testing ability of equipment to withstand high or low temperatures, temperature shocks and cycling. It sometimes includes humidity test provisions.

ConUS. Continental United States.

CONVAIR. A Division of General Dynamics Corporation; San Diego, California.

CONVECTION. (1) Motions occurring within a fluid due to differences in temperature and density. (2) The transfer of heat by the movement of matter. (3) The transfer of mass by streaming motion. (4) The vertical movement of a limited mass of air.

CONVECTIVE INSTABILITY. The condition of a body of air having a distribution of temperature and moisture in such a manner that lifting of the body will cause it to become unstable. Also called "potential instability."

CONVERSION KIT. A modification kit used to change a system for improved performance, modernization, reliability, etc. The kit is usually complete in every detail and may be used in the factory or field. The makeup of the kit may be different for these uses.

CONVERTER. (1) A machine or device that changes alternating current to direct current, or the converse. (2) A machine or device

that changes the frequency of periodic phenomena. (3) A machine or device that changes one type of signal to another (e.g., AM to FM).

"COOKIE-CUTTER" INTAKE. A normal shock intake for a ramjet engine; a sharp edged intake for any air-breathing engine.

COOLDOWN. A process for reducing the temperature of containers and associated piping for cryogenic materials (e.g., liquid oxygen, liquid nitrogen) to reduce thermal shock and boiloff. In this process liquid oxygen or liquid nitrogen are flowed through the container and allowed it to vaporize or boil off, thereby absorbing heat from the container to reduce its temperature.

COOLING, FILM METHOD. A cooling technique wherein a liquid is admitted through small holes into a jet or rocket engine combustion chamber or nozzle of a rocket near possible hot spots. Cooling is by evaporation of the liquid film. This method is sometimes used in conjunction with **cooling, regenerative**.

COOLING, REGENERATIVE. A cooling technique where a liquid which requires heating is circulated through a jacket-enclosed **combustion chamber** of a rocket. The rocket fuel is often preheated in this manner prior to its combustion.

COOLING OF ROCKET MOTORS. From the standpoint of motor efficiency, high combustion temperatures yield greater energy release and higher exhaust velocities. With ordinary metallic construction, these desirable temperatures would soon destroy the rocket engine. Measures must be taken, therefore, to keep the motor temperatures within limits which will not destroy the mechanical properties of the metal from which the motor is made. Temperature control is accomplished in several ways. Fuels may be burned in non-stoichiometric proportions to oxidants in order to reduce combustion temperatures. Water may be mixed with the fuel (or more commonly) the oxidant. Finally, the motor walls may be cooled. Three general methods to effect this cooling are defined under **cooling, film method; cooling, regenerative; and cooling, sweat**.

COOLING, SWEAT. A cooling film technique employing a porous chamber wall

through which a liquid slowly flows. Cooling is effected by evaporation of the liquid, by conduction or by a combination of these.

COOPERATIVE PHENOMENON. Any process for whose occurrence the simultaneous interaction between several molecules or systems is required. Most typical are order-disorder transformations, and ferromagnetism, where every atom in a crystal may participate.

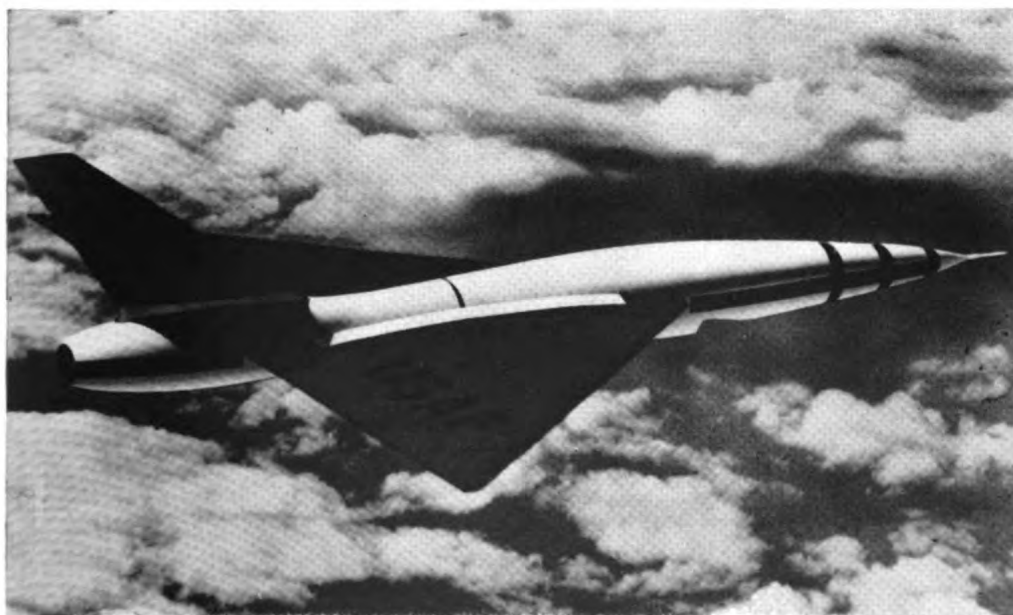
COOPERATIVE SYSTEMS (INSTRUMENTATION). Instrumentation systems which require transmission of information from a ground station (remote) to the missile in flight; processing of the information by the missile borne equipment and re-transmission of the processed data to the originating and/or other remote ground stations. (E.g., **Azusa, Dovap.**)

COORDINATED TOOLING. Tooling used in production to insure the matching of equipment or assemblies, usually from two sources of supply. Coordinated, or master, tooling provides assurance that parts or assemblies which fit the tools will fit with each other.

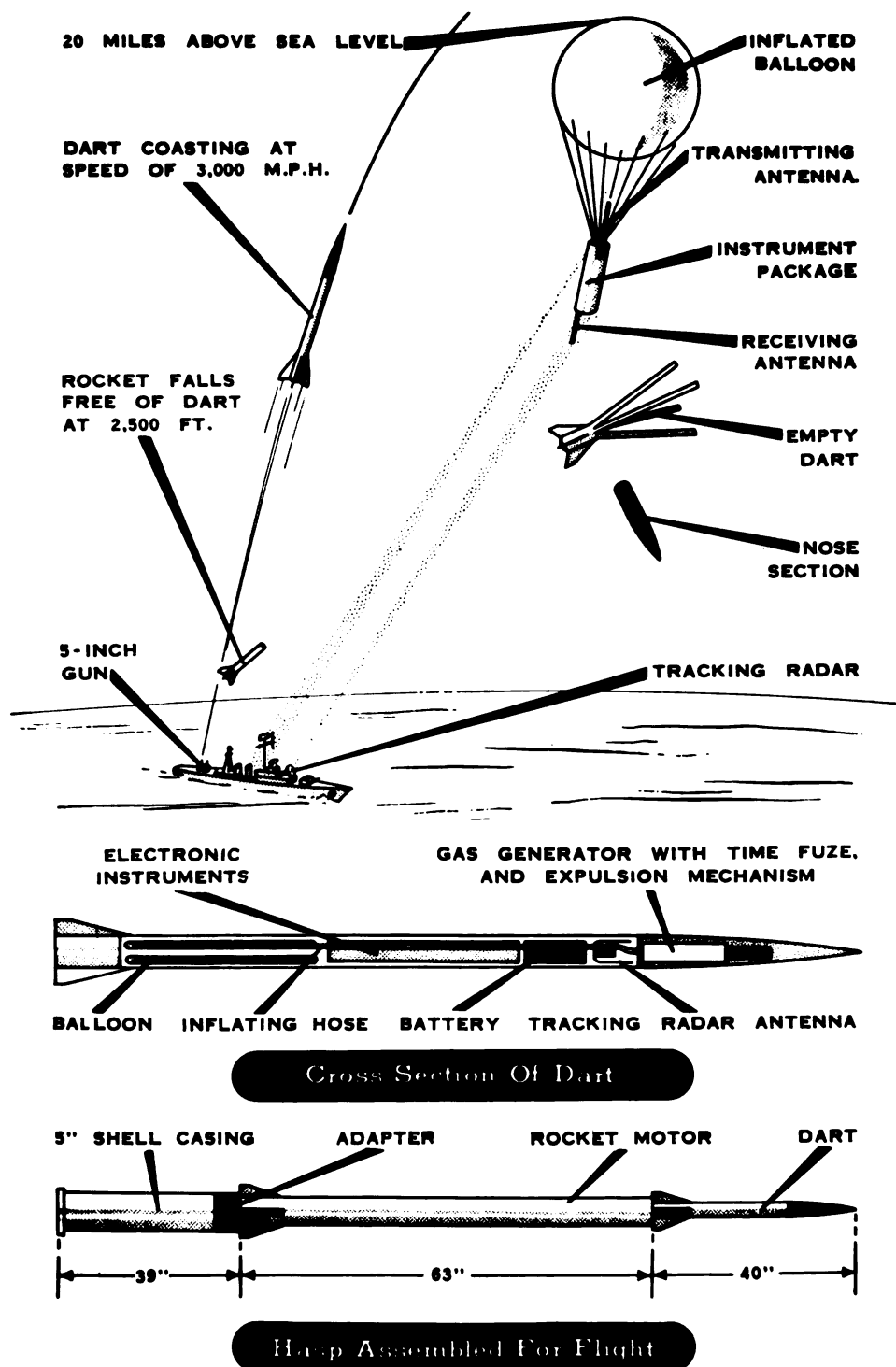
COORDINATE SYSTEM. A coordinate is one of a set of **numbers** used to locate a point relative to a system of **axes** or **surfaces**, the coordinate system. (1) The simplest and most frequently used system is called rectangular Cartesian. Choose three mutually perpendicular straight lines, the coordinate axes, intersecting at a point *O*, the origin. Label the axes *OX*, *OY*, *OZ* and imagine that *OX* and *OY* are drawn on a piece of paper, the *XY*-plane, so that the positive direction of *OX* points toward the reader's right and the positive direction of *OY* points toward the top of the page. The positive direction of *OZ* is then taken upward from the page, toward the reader. This arrangement determines a right-handed coordinate system, the most common one. If a pair of axes is exchanged, the system is then left-handed. A unit distance of convenient size is selected and this distance is marked off on each axis, repeatedly and in both positive and negative directions. Now suppose three numbers are given, one each in multiples (or fractions) of the unit distance along each axis. The numbers then locate the position of a point in space, relative to the coordinate system and they are the co-



New member of the Air Force jet interceptor team is the GAR-2A FALCON (left), infrared-seeking guided missile designed and produced by Hughes Aircraft to complement the GAR-1D FALCON (right), which uses radar guidance. (*U.S. Air Force Photograph*)



The Air Force SM-73 GOOSE missile, under development by Fairchild Engine and Airplane Corp., Hagerstown, Maryland, is shown here during a flight test at the missile test center, Cape Canaveral, Florida. Listed in the "penetration aid" category, GOOSE would be launched ahead of or in concert with strategic missiles and manned bombers, to serve as a diversion or decoy against enemy air defense systems. (*U.S. Air Force Photograph*)



Artist's conception of a supersonic antiaircraft missile which is being converted to peaceful use as a collector of weather data by scientists at the Naval Ordnance Laboratory, White Oak, Maryland. Named the HASP (High Altitude Sounding Projectile), the rocket is a single-stage, solid-propellant type, and can reach altitudes above 100,000 feet. The HASP can be fired from conventional five-inch batteries aboard ships at sea and will enable them to forecast the weather ahead quickly and accurately. The rocket has a balloon to lower it slowly to earth, while automatic electronic receiver-transmitter equipment supplies weather data to an electronic computer aboard ship. (*U.S. Navy Photograph*)

ordinates of the point. A suitable notation is (x, y, z) . If one coordinate is zero, the point is on one of the three possible planes of the system, a coordinate surface; if two coordinates vanish, the point lies at the intersection of two coordinate surfaces, which is a

ordinate surfaces are: (1) concentric **spherical surfaces** about the origin, $r = \text{const.}$; (2) right circular **conical surfaces** with apex at the origin and axis along the Z -axis, $\theta = \text{const.}$; (3) planes from the Z -axis, $\phi = \text{const.}$ The range of the variables is $0 \leq r \leq \infty$;

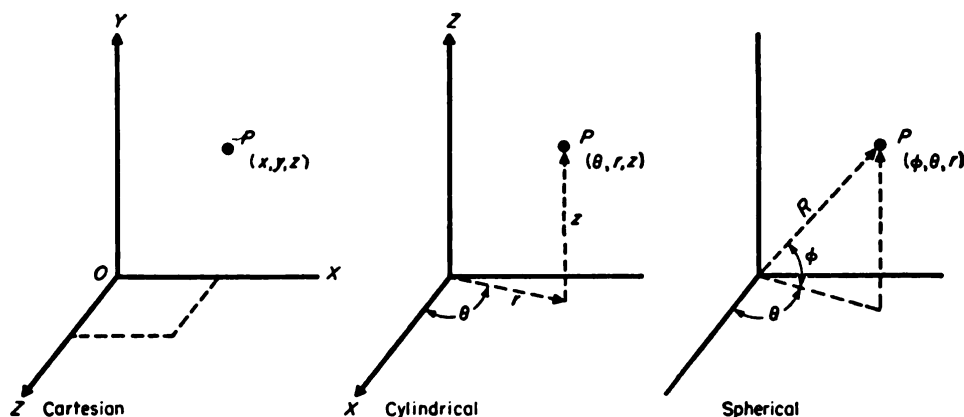


Fig. 1. Common coordinate systems.

coordinate axis; if all three coordinates are zero, the point is at the coordinate origin. (See Fig. 1.)

When a given point lies on a coordinate surface, it is customary to use the XY -plane. The horizontal coordinate is then called the *abscissa* and measured along the X -axis while the vertical, or Y -coordinate, is called the *ordinate*.

These conceptions can be generalized extensively. When the surfaces are mutually perpendicular, the system is curvilinear or orthogonal; when the surfaces are orthogonal planes, the system is rectangular; if the surfaces do not intersect at right angles, the system is said to be affine or non-orthogonal. A Cartesian coordinate system could mean a rectangular system or a system of planes not at right angles to each other. The latter is called an oblique coordinate system. However, the term Cartesian generally means rectangular Cartesian. (2) After Cartesian coordinates, the next most often used type is the polar coordinate in two or three dimensions, the latter being called spherical polar coordinates. In this system the three coordinates of a point are: (1) the radius vector r from an origin or pole to the point; (2) the colatitude θ , an angle made by r and a fixed axis, the polar axis; (3) the longitude ϕ made by the plane of θ with a fixed plane through the polar axis, called the meridian plane. The co-

$0 \leq \theta \leq \pi$; $0 \leq \phi \leq \pi$. In terms of a right-handed rectangular system with the same origin

$$\begin{aligned} x &= r \sin \theta \cos \phi; & r^2 &= x^2 + y^2 + z^2 \\ y &= r \sin \theta \sin \phi; & \theta &= \cot^{-1} z / \sqrt{x^2 + y^2} \\ z &= r \cos \theta; & \phi &= \tan^{-1} y / x \end{aligned}$$

The name "spherical" arises from the fact that if the length R is fixed (as in the case of the earth's "sphere"), then all points on it can be designated by the use of two angles measured from the central origin (e.g., latitude and longitude). Spherical coordinates are used to designate astronomical positions on the **celestial sphere** by means of azimuth and elevation measured from its center.

The term "space coordinates" is sometimes used in data reduction technology to refer to a three-dimensional system (usually in rectangular coordinates), which may have as its origin some point on the earth's surface, such as the launching point of a missile, but which then has no other direct relation to the earth. Thus, the coordinates of a space coordinate system are not based upon the distance from the surface of the earth. This fact does not become significant except for long ranges, in which negative values may occur as the missile crosses the downrange coordinate axis in its descending trajectory. Coordinates related to the earth, which yield true distance

measures on the surface of the earth, are called "Earth Fixed Coordinates" and are merely space coordinates to which has been applied a correction for the curvature of the earth. In describing the motions of a rocket in space and its orientation during such motion, the following notation and coordinate system is conventional (see figure 2): X , downrange,

or the "total departures." A plane rectangular coordinate system is used in mapping areas of such limited extent that the errors introduced by substituting a plane for the actual curved surface of the earth is within the order of accuracy desired. In mapping, the north and east directions are positive and the south and west directions are negative. (b)

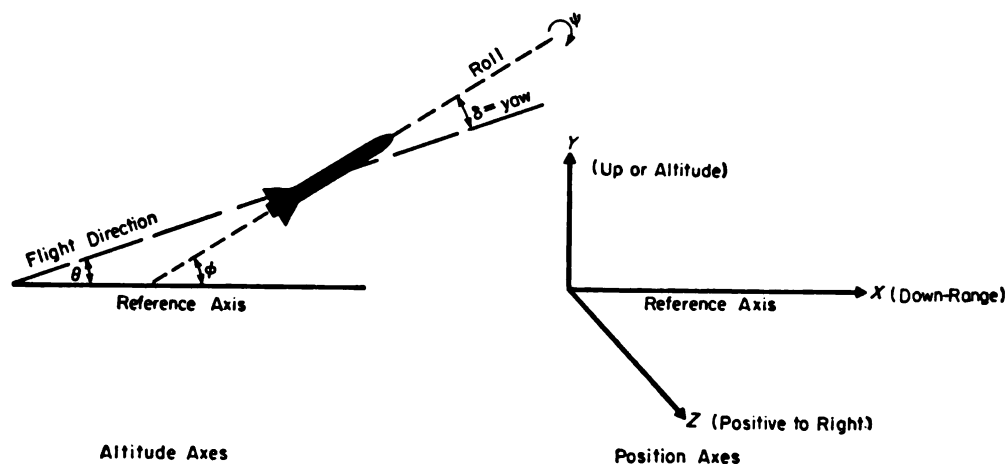


Fig. 2. Missile coordinate systems.

Y , up (altitude), and Z , cross-range. X increases downrange, Y increases with altitude and Z is positive to the right. The attitude data on a missile are given by four angles as follows: θ , flight direction with respect to reference axis (usually horizontal), ϕ , pitch angle (i.e., the deviation of the longitudinal axis of the missile off the desired flight direction), ϕ_r , the roll angle (i.e., the angular displacement of the missile around its longitudinal axis), and ϕ_{yaw} , the yaw angle (or lateral deviation from flight direction as measured from the flight direction). (3) In surveying and mapping, several systems employing linear or angular quantities to designate the position of a point are used: (a) Plane rectangular coordinates (also called "plane coordinates") are a system of coordinates in a horizontal plane, denoting points by means of two distances perpendicular to each other measured from an arbitrary origin. The two reference lines at right angles to each other passing through the origin are called the "coordinate axes." The distances parallel with the true or arbitrarily assigned north-south axis are called the "ordinates," (Y -coordinates) or the "total latitudes." The distances parallel with the true or arbitrarily assigned east-west axis are called the "abscissas," (X -coordinates),

Grid coordinates are plane rectangular coordinates based on and mathematically adjusted to a map projection in order that geographic position (latitude and longitude) may be readily transformed into plane coordinates and the computations relating to them made by the ordinary methods of plane surveying. (4) For the location of celestial bodies, there are two common coordinate systems: (See Fig. 3) First, the **Equatorial Coordinate System** in which the **celestial equator** is the fundamental reference and hour circles are the secondary reference. A body located in this system would have two angular values as follows: right ascension (α), which is the angular displacement measured eastward on the celestial equator from the vernal equinox (γ). The units of measure are hours, minutes and seconds, with 24 hours being one complete turn about the celestial equator; declination, (δ), which is the angular displacement measured north or south on the particular hour circle through the body. Second, there is the **Horizon System**. For this the horizon is defined as the intersection of the celestial sphere and a plane perpendicular at the earth's surface to a line between the zenith and the nadir (i.e., the point on the celestial sphere directly "above" the observer as projected through the

center of the earth). The Horizon System uses two angles: azimuth, which is the clockwise angular displacement on the horizon from the north point to the front of the vertical circle through the celestial body, and altitude, which is the angular displacement measured upward on a vertical circle through the celestial from the horizon. This system is good only for one time and position. In order to locate oneself on the surface of the earth using the coordinates of celestial bodies, the observer would require a line of sight instrument (e.g., a sextant), a horizontal reference, the time, and a table of star (celestial body) coordinates for relating the measurements to actual position.

COPPER. Metallic element. Symbol Cu. Atomic number 29.

CORDITE. A colloidal rocket propellant composed of guncotton, nitroglycerin and mineral jelly, mixed and formed with the aid of solvents.

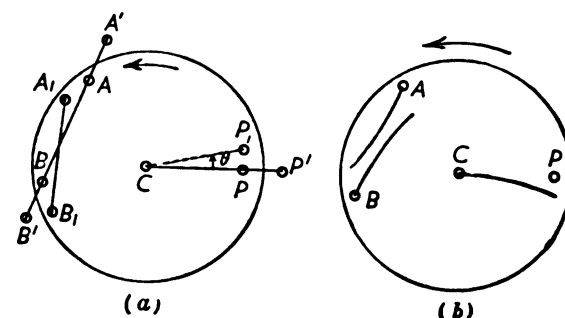
CORE. (1) A magnetic core is an important element in many applications in electrical design. Electromagnetic equipment, as exemplified by the transformer, the motor and the generator, have electrical circuits, usually of copper conductors, and magnetic circuits. The magnetic circuit follows a path largely contained in a core composed of iron or iron alloys. The purpose of the core is to offer a low-reluctance path for the magnetic flux established by the electrical circuits, and its success in this respect is measured by its permeability. (2) In a nuclear reactor, the region containing the fissionable material; in a heterogeneous reactor, the region containing fuel-bearing cells. (3) In an atom, the aggregate consisting of the nucleus plus all electrons in closed shells. The valence electrons may often be considered to be moving in a field due to the spherically symmetrical charge $+ze$ of the core, z being the number of valence electrons.

CorEng. Corps of Engineers.

CORIOLIS EFFECTS. Any object moving above the earth with constant space velocity is deflected relative to the surface of the rotating earth. This deflection was first discussed by the French scientist Coriolis about the middle of the last century, and is now usually

described in terms of the Coriolis **acceleration** or the Coriolis **force**. The deflection is found to be to the right in the northern hemisphere and to the left in the southern.

As a first approximation to the problem we assume that an observer is at the center (C) (see figure) of a disk that is rotating with con-



Coriolis effects.

stant angular velocity ω . In Fig. (a) the observer can see objects off the disk and is conscious of the rotation. At a given instant, when the object P on the disk is directly in line with the point P' off the disk, the observer fires a shot at P . During the time (t) that is required for the shot to move over the distance CP at speed v ($CP = vt$), the disk will turn through the angle θ ($\theta = \omega t$). The observer notices that the bullet misses the point P , but that it hits P' . In Fig. (b) the observer's "world" is limited to the rotating disk and he has no way of knowing that his world is in rotation. Under these conditions when he fires a shot at P he will notice, as before, that the bullet misses P , and he will also determine that the shot follows a curve, similar to that shown, in his world. The same effects will be observed no matter where the observer is located in his world or in what direction he aims his shot (e.g., from A in direction BB' , or from B toward AA'). The deflection is always to the right with the direction of rotation indicated in the figure, and would be to the left if the direction of rotation were reversed.

The importance of the Coriolis effect lies in the part it plays in modifying the flight motion of a rocket, missile or spaceship. Corrections to the path of such objects are necessary to make their calculated paths intersect a fixed or moving point on earth or one of the other bodies in the universe.

Quantitatively, there are three effects of Coriolis on the trajectory of a missile; these are on the time of flight (t_e), lateral deviation

(Z_e), and *range deviation* (X_e). These are given by the following mathematical expressions:

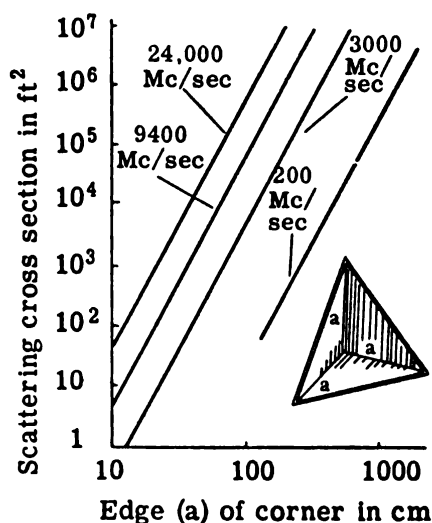
$$t_e = \frac{2\omega v_0^2 \sin \theta \cos \lambda \sin 2\phi}{g^2}$$

$$Z_e = \frac{4\omega v_0^3 \sin^3 \phi}{g^2} (\cot \phi \sin \lambda - \frac{1}{3} \cos \theta \cos \lambda)$$

$$X_e = \frac{4\omega v_0^3 \sin \theta \cos \lambda \sin^3 \phi}{g^2} (\cot^2 \phi - \frac{1}{3})$$

where ω is the angular velocity of the earth, v_0 is the initial velocity of missile, θ is the aiming azimuth, λ is the latitude, ϕ is the angle of departure (i.e., cut-off angle of missile) with respect to horizontal, and g is the acceleration of gravity.

CORNER REFLECTOR. (1) A reflector consisting of two or three mutually-intersecting, conducting surfaces. Corner reflectors may be dehdral or trihedral. Trihedral reflectors may be used as radar targets. (2) A reflector which consists of two plane-conducting surfaces set at an angle of 45° to 90° with the driven element on a line bisecting the angle. The reflecting surfaces are not necessarily solid, but can be made from wires spaced about 0.1 wavelength apart. In a given amount of space, the corner reflector gives better directivity than the parabolic reflector. (See figure.)



Maximum scattering cross section of triangular corner reflector.

CORONA. (1) **Diffraction** of light from either the sun or moon through **cloud water-**

droplets produces a corona or series of colored rings which appear about the celestial body but actually are at the cloud height. Corona differs from halo in that the latter is due to refraction by ice crystals. Reddish colors always occupy the outer part of the ring. (2) The luminous region which may be seen about the sun during a total solar eclipse. (3) The corona discharge, which is a discharge brought about as a result of the ionization of gas surrounding a conductor, which occurs when the **potential gradient** exceeds a certain value but is not sufficient to cause sparking.

CORONA DISCHARGE. Corona (3).

CORPORAL. A U.S. Army surface-to-surface missile manufactured by the Firestone Tire and Rubber Company. Original development on the missile was done at the Guggenheim Aeronautical Laboratory of the California Institute of Technology (GALCIT). It used a radio guidance system (in the service model the guidance equipment was made by Gilfillan Associates and Motorola). The launching weight of the Corporal was about 12,000 pounds, length 46 feet, diameter 2.5 feet, range about 75 miles, with a liquid rocket powerplant produced by Ryan Aeronautical Corporation. The Corporal was the first ballistic missile of the vertically launched type put into operation by the U.S. Army. Corporal missile battalions were sent to Europe in the early 1950's. The Corporal missile was the first guided missile capable of carrying an atomic warhead. Propulsion system was of a bi-propellant liquid type using nitric acid and aniline. This missile was also called Corporal E and SSM-A-17. (See **missile, guided**.) (See also illustration facing Page 122.)

CORRECTION. The quantity which is added to a calculated or observed value to obtain the correct value. The correction is the negative of the **error**.

CORRECTION FACTORS. In many fields of applied science, theoretical values of parameters are never attained because of the impossibility of creating perfect systems. In rocket propulsion, correction factors are required for many non-ideal conditions which cause design conditions not to be attained. The necessary corrections to these parameters are frequently determinable in advance either from past experience or by calculation. Cor-

rection factors take into account incomplete combustion, wall friction, non-axial flow, non-ideal gas conditions and other factors. Examples are:

$$\text{Thrust correction factor} \quad \eta_F = \frac{F_{\text{actual}}}{F_{\text{theoretical}}} = \eta_v \eta_d$$

$$\text{Effective velocity correction factor} \quad \eta_v = \frac{C_{\text{actual}}}{C_{\text{theoretical}}}$$

$$\text{Discharge correction factor} \quad \eta_d = \frac{\dot{m}_{\text{actual}}}{\dot{m}_{\text{theoretical}}}$$

CORRECTION MANEUVER. Maneuver, correction.

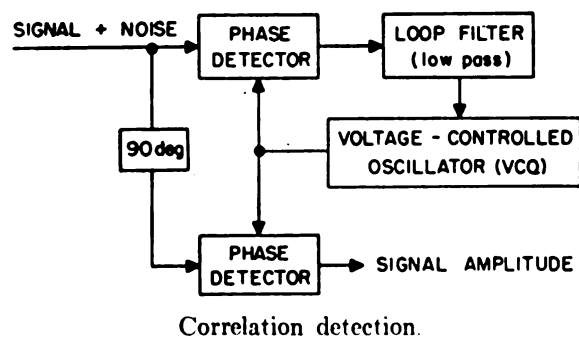
CORRECTION TIME. The time required for the controlled variable in an **automatic controller** to reach and stay within a predetermined band about the control point following any change of the independent variable or operating condition.

CORRELATION COEFFICIENT. A measure of the dependence of one quantity on another.

CORRELATION DETECTION. One means of employing some of the *a priori* information about signal characteristics in order to achieve high signal-to-noise ratios in the detection process. The basic operation of correlation detection is the multiplication of incoming signal plus noise ($S + N$) by a locally generated estimate of signal S^* which embodies to the greatest possible extent the known signal characteristics. (See figure.) This product

$$S^* (S + N) = SS^* + NS^*$$

when averaged by a low-pass filter, yields the correlation coefficient $(SS^*)_{av}$ contaminated by



a small amount of noise $(NS^*)_{av}$. This process is said to be a "linear" in that the signal-

to-noise ratio at the output SS^*/NS^* is the same as that at the input S/N . This linear detection process is to be contrasted with square-law detection in which the input signal plus noise ($S + N$) is passed through a square-law detector forming

$$(S + N)^2 = S^2 + N^2 + 2SN$$

In this process the desired signal appears as S^2 contaminated by noise ($N^2 + 2SN$). Furthermore, the output signal-to-noise ratio is not equal to that at the input

$$\frac{S^2}{(N^2 + 2SN)} = \frac{S/N}{(2 + N/S)}$$

Thus, the signal-to-noise ratio for square-law detection is less than that for correlation detection by the factor $(2 + N/S)$. The degradation of signal-to-noise ratio for a square-law detector becomes particularly important when the signal-to-noise ratio is less than unity. For instance, when $S/N = 0.10$ (-20 db), the degradation factor is 12. (See **phase-lock detection**.)

CORROSION TEST. A test designed to determine the adequacy of a part for withstanding corrosion. Usually a salt spray test is used.

CORUSCATOR. A highly compressed slug of two or more solid reagents which on proper ignition, liberates heat and light explosively, but without flying apart, since all their reaction products are solid or liquid and not gases. Coruscators are also called coruscatives or heat explosive materials.

CORVUS. (1) A Navy air-to-surface solid propellant rocket missile undergoing development for the U.S. Navy Bureau of Aeronautics, by Temco, W. L. Maxon, and Reaction Motors. (2) A small constellation containing no particularly bright or interesting stars. This group of stars has long been a friend to lovers of the sea because of its resemblance to the "fore and aft" sail of a cutter. For this reason the constellation is frequently referred to by sailors as "the cutter's mainsail." On a clear moonless night the resemblance to the sail is very remarkable, even the "step" of the mast and a small "pennant" flying from the gaff being discernible.

COSMIC RAYS. A highly penetrating radiation apparently reaching the earth in all di-

reactions from outer space. The existence of this radiation was first suspected from the discharge of electroscopes in air free from all known ionizing influences, the rate of discharge increasing as the electroscope was carried to higher altitudes. The atmosphere apparently absorbs a measurable portion of the rays, but traces of their effect persist even at depths of many feet below water or below the ground. Professor R. A. Millikan and his associates, who have studied the distribution and absorption of the rays very thoroughly, find that the rays are of nearly the same intensity from all parts of the celestial sphere, and that, as they proceed through an absorbing medium, they show evidence of unequal absorption rates. Experimental observations show that the cosmic rays entering our atmosphere are almost entirely composed of positively-charged atomic nuclei. About two thirds of these so-called primary cosmic rays are protons, and the other third (by mass) are about 90 per cent α -particles and 10 per cent heavier nuclei like carbon, nitrogen, oxygen, iron, etc. Upon entering the atmosphere, a high-energy primary particle soon collides with another atomic nucleus, splitting one or both particles into a number of smaller nuclear fragments, each one of which carries away some of the primary's energy. These high-speed particles in turn collide with other nuclei, further dividing their energy to produce other high-speed particles. All of these with the exception of the primary particle are called secondary cosmic rays.

Mesons of various kinds are present in cosmic rays, being formed most generally by collision of primary cosmic rays with air nuclei, high in the atmosphere. In these collisions positively and negatively charged π -mesons are produced, along with neutral π -mesons, and other nuclear particles, as stated above. The charged π -mesons decay principally into charged μ -mesons and **neutrinos**; and the μ -mesons decay in turn into electrons and neutrinos. The uncharged π -mesons decay into γ -rays, which create in the upper atmosphere cascade showers of electrons by electron pair-production and bremsstrahlung.

COSMIC RAYS, ALTITUDE EFFECT ON. The intensity of cosmic rays as a function of altitude shows a maximum at a distance below the top of the atmosphere corresponding

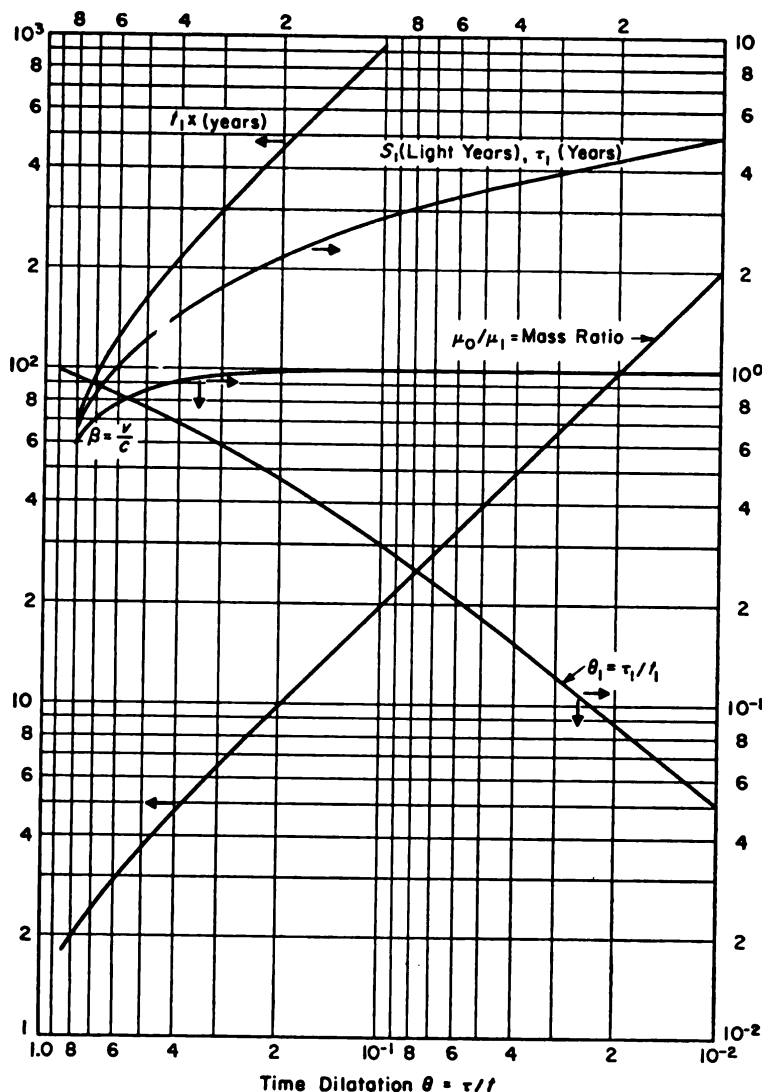
to a pressure of about 45 mm Hg. This maximum is due to the interaction of primary cosmic ray particles of extremely high energies with atomic nuclei in the top layer of the atmosphere.

COSMONAUTICS. The ultimate space flight operations are those connected with interstellar or even intergalactic flight. The overwhelming distances involved in such operations are illustrated by the fact that, if one escapes from the solar system at a speed of 100 km. per second (328,000 ft. per second) it requires 1,200 years to reach the nearest star (α Centauri). At 1,000 km. per second it takes about 240,000,000 years to reach the nearest galactic system (the Andromeda nebula, 805,000 light years away). Thus, taking the human life span to be 60 years, cosmonautics at such velocities involves transfer periods ranging from the order 20 to 4×10^6 generations. A speed to 100 km. per second or 1,000 km. per second is extremely high by today's standards, but it is a small fraction of the velocity of light. If one approaches the velocity of light, a new effect, the **relativistic time dilatation**, may permit us to cover vast stretches of galactic or intergalactic space within the span of one human life. The relativistic flight at first glance appears to be merely a matter of sufficient energy production. However, even if this were so, the energy requirements are so staggering that probably only complete conversion of matter to radiation i.e., propulsion by radiation pressure yielding a specific impulse of 30,000,000 lb. sec./lb., appears adequate. This can be seen from the accompanying table which summarizes the figures of relativistic cosmonautics.

RELATIVISTIC FLIGHT MECHANICS*

$\theta = \frac{v}{c}$	0.8	0.6	0.4	0.2	0.1	0.01
$\beta = v/c$	0.6	0.8	0.916	0.979	0.996	0.9995
$\gamma = \frac{1}{1-\beta^2}$	0.693	1.099	1.563	2.29	2.994	5.298
$\theta_1 = \frac{v_1}{c}$	0.924	0.8239	0.6824	0.4674	0.300	0.053
τ_1 (year)	0.658	1.042	1.484	2.175	2.84	5.03
t_1 (year)	0.712	1.264	2.175	4.653	9.438	94.9
S_1 (light years)	0.658	1.04	1.48	2.175	2.836	5.027
μ_0/μ_1	2.0	3.0	4.775	9.874	19.97	199.9

* Values are based on the photon rocket and on loss-free energy conversion, hence, on Ackeret's relativistic mass ratio equation in the form $\mu_0/\mu_1 = \sqrt{\frac{1+\beta}{1-\beta}}$ and on constant acceleration $a = 10m/sec^2 = 1.019367 g$. If energy conversion less than 100 per cent is assumed, divide $\ln(\mu_0/\mu_1)$ by the efficiency $\eta < 1$ and find the new mass ratio.



Time dilation relationships.

Explanation of table and graph: First line ($\theta = \tau/t$) gives the time dilatation, i.e., states how much slower time τ passes in space ship than time t on Earth, *once* the space ship has reached final and constant velocity β . Second line ($\beta = v/c$) = final velocity v in fractions of light velocity c . Third line $v = \frac{\alpha\tau}{c}$ gives the ratio of velocity $v = \alpha\tau$ measured on board as product of acceleration α and board time τ to light velocity c . Fourth line θ_1 gives the time dilatation during the acceleration period up to velocity β (acceleration is $\alpha = 10 \text{ m/sec}^2 = 1.019367 \text{ g}$). Fifth line: Time measured on board during acceleration period. Sixth line: Time measured on Earth during acceleration period. Seventh line: Distance

traveled during acceleration period. Eighth line: mass ratio required to reach velocity β at an exhaust velocity equal to light velocity.

It has been proposed that the application of the general theory of relativity, which is embodied in this article, be checked experimentally, as for example by missiles carrying masers, or other accurate time-measuring devices.

To illustrate the use of the table, for a specific example the table reads as follows: In order to obtain a time dilatation factor of $\theta = 0.1$ (10 years passing on earth within one year on-board time), the vehicle must be accelerated to 99.5 percent of light velocity ($\beta = 0.995$). In order to attain these conditions, a certain period of acceleration from rest is required. Independent of the magnitude of

acceleration period θ_1 is 0.3 (as distinguished from the dilatation θ after $\beta = 0.995$ is attained). If the propulsion system accelerates the vehicle at a rate of 10 m per second per second (roughly 1 g), then the crew in the vehicle measures a time of 2.84 years, while an observer on the earth "observes" the engine cut-off 9.438 years after departure of the vehicle. He measures that the vehicle's cut-off point lies at a distance of 2.836 light years from the earth. The crew finds at cut-off that the mass of the ship is only about $\frac{1}{20}$ of the mass at departure from earth.

If the crew turns the ship around immediately after cut-off and starts deceleration at 10 meters per second per second, then the vehicle's velocity is back to zero with respect to the solar system at a distance of $2s' = 5.67$ light years from the sun, and after 18.8 years have passed on earth. The crew has grown older by 5.68 years since departure, and the mass of the vehicle is now only about $\frac{1}{20}^2 = \frac{1}{400}$ of its mass at departure. Thus, 5.67 light years would be the minimum radius of operation under these conditions. (α Centauri is 4 light years distant.)

COSMOS. The totality of the observed and postulated physical whole, conceived as an orderly and harmonious system.

COTAR. A passive range instrumentation and/or safety system designed to provide position information by determining the angle between the remote ground based antenna system and a missile transmitter (telemetry or other) by a phase comparison technique. The system, developed by Cubic Corp., does not require a missile-borne **transponder**.

COULMER ARRAY (ANTENNA). A planar antenna array consisting of non-resonant elements stacked vertically and horizontally with respect to each other. The result is both vertically and horizontally polarized waves to produce a high gain antenna.

COULOMB. A unit of electrical charge, abbreviation coul or cb.

(1) The absolute coulomb is defined as the amount of electrical charge which crosses a surface in one second if a steady current of one absolute **ampere** is flowing across the surface. The absolute coulomb has been the legal standard of quantity of electricity since 1950.

(2) The International coulomb, the legal standard before 1950, is the quantity of electricity which, when passed through a solution of silver nitrate in water, in accordance with certain definite specifications, deposits 0.00111800 gm of silver. 1 Int. coul = 0.999835 abs. coul.

COULOMB LAW (ELECTROSTATICS).

The force between two point charges in free space is a pure attraction or repulsion, and is given by

$$F = \frac{q_1 q_2}{\epsilon_0 r^2}$$

where q_1, q_2 are the magnitudes of the charges, r is their separation, and ϵ_0 is a constant of nature. The numerical value of ϵ_0 depends upon the system of units used. When the charges are immersed in a homogenous medium, which extends to distances much greater than r in all directions

$$F = \frac{q_1 q_2}{\epsilon r^2}$$

where ϵ is the **permittivity**, or absolute dielectric constant of the medium.

COULOMB LAW (MAGNETISM). The force between two magnetic poles is given by

$$F = \frac{\mu p_1 p_2}{r^2}$$

where μ is the absolute **permeability** of the intervening medium.

COUNTDOWN. The sequence of events involved in the preparation and launching of a missile. Countdowns for research and development missiles may last as long as 8-10 hours; for tactical missiles, only a few minutes. The term countdown refers both to the sequence of events required to prepare the missile and to the written schedule of them. A countdown is actually a "checkoff list" for the conduct of a missile launch. Everything to be done is written down opposite a set time for that action. The time intervals diminish toward the launch action which is designated as "Zero Time." All times before launch are denoted as "Minus Time," as X - 2 minutes or X - 2 hours (read as X MINUS TWO HOURS). All times after launch are "Plus Time," as X + 10 seconds. Some conventions hold that the launch day is designated as

"F-Day" (firing day), and all times before or after expressed in units of days will be $F - 3$ days or $F + 2$ days as the case may be. The actual launch minute will be "T-Time" and all times in minutes before or after are designated as $T - 2$ minutes or $T + 3$ minutes, for example. Another convention is that all time before launch is X-time down to X-0, after which it becomes simultaneously and subsequently T-time, i.e., all plus time is T-time and all minus time is X-time. As the preparations for launch progress, the count gets closer and closer to Zero Time. All during this preparation the controlling authority causes a verbal or other notice to be given of the countdown time.

COUNTDOWN PROFILE. A graphical representation of the progress of a missile launching preparation. On its **countdown times** (i.e., X-360 min, X-300 min, etc.) are plotted as ordinates descending from the top of the graph downward to X-0, and clock times are plotted as abscissas. If the launching proceeds according to schedule, the profile has a constant slope, with equal intervals of countdown time corresponding to equivalent clock time intervals. If there is a "hold," the plot will stop progressing toward X-0, and will stretch out horizontally along the clock time axis, creating a plateau whose length is equal to the "hold." It is conventional to label plateaus with brief explanations.

COUNTER. (1) A device for counting **ionizing events**. The term may refer to a complete instrument or to the detector, usually a device of the Geiger or scintillation type. (2) A device capable of changing from one to the next of a sequence of distinguishable states upon each receipt of a discrete input signal. The term counter is in some cases used to mean accumulator. (3) In mechanical analog-computers, a means for measuring the angular displacement of a shaft.

COUNTER, COINCIDENCE. An arrangement of **counters** and circuits which records the occurrence of counts in two or more detectors simultaneously or within an assignable time interval.

COUNTER RESOLVING TIME. The minimum time interval between counts that can be detected. The word may refer to an electronic circuit, to a mechanical recording de-

vice, or to a radiation counter. In the latter case, this quantity pertains to the combination of tube and recording circuit.

COUNTERMEASURES. Actions taken, or devices or techniques employed, to impair the operational effectiveness of enemy actions; or more specifically, to prevent a weapon or guided missile from achieving its objective. Countermeasures are generally considered to be either physical or electronic in nature.

COUNTERMEASURES, ACTIVE ELECTRONIC. Electronic countermeasures involving actions taken which are of such nature that their employment is detectable by the enemy.

COUNTERMEASURES, ELECTRONIC. Countermeasures effected by the use of electromagnetic radiation.

COUNTERMEASURES, PASSIVE ELECTRONIC. Electronic countermeasures involving actions taken which are of such nature that their employment is not detectable by the enemy.

COUNTERPOISE. A system of wires or other conductors, elevated above and insulated from the ground, forming a lower system of conductors of an **antenna**.

COUPLE. A system of two forces, equal in magnitude, parallel in direction and opposite in sense.

COUPLED CIRCUIT. Circuit, coupled.

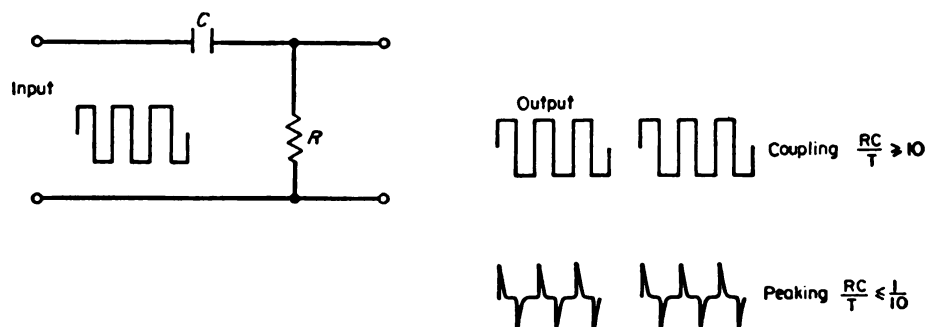
COUPLED MODES (PRINCIPAL MODES). In mechanical systems two frequencies exist where the amplitudes of the motion consisting of a combined rotation and translation are a maximum. These are called the coupled modes or principal modes and they may be calculated from the uncoupled modes. The resonant frequencies thus determined are very near the natural frequencies of the system, and the deformation configurations are called the normal or principal modes of vibration.

COUPLED OSCILLATOR. Oscillator, coupled.

COUPLER. A device used to transfer electrical energy from one circuit to another.

COUPLING. (1) An interaction between systems, or between properties of a system. When there is little interaction, the coupling is sometimes said to be "loose"; with considerable interaction, it is called "tight." (2) In induction heating usage and other induction apparatus, the percentage of the total magnetic flux produced by an inductor which is effective in heating a load or charge.

COUPLING CIRCUIT. A circuit which transfers energy effectively by induction to another circuit. A common type is a series RC (resistance-capacitance) circuit having a long time constant with the output taken from across the resistor. It is exactly the same configuration as the RC peaking circuit with changed values of the components. Such circuits are used to transfer energy from one circuit to another with as little amplitude reduction and distortion as possible. For coupling align $RC/T \geq 10$. To couple a sine wave the capacitive reactance should be equal or less than $1/10$ th R (i.e., $X_c \leq R/10$). This holds attenuation and phase shift to a minimum. To couple a square wave, $RC/T = 10$ or more; for *peaking*, $RC/T = 1/10$ or less. (See figure.)



Coupling-peaking circuit.

COUPLING LOOP. A device for coupling an external circuit to a **waveguide** or **resonator**. It consists of a small loop placed at or near a point of high magnetic field strength in the guide or resonator, and turned in such a position that its plane is normal to the flux lines. It is designed to transfer energy to or from the external circuit.

COUPLING, POSITIVE. The **coupling** (or mutual inductance) between a pair of coils may be either positive or negative according to the choice of reference direction in the corresponding **meshes**. If an increasing current

in one coil induces a voltage in the other, having the same sense as an increasing current in the second coil itself would produce, the mutual inductance is positive.

COUPLING PROBE. A device for coupling an external circuit to a **waveguide** or **resonator**. It consists of a probe parallel to the electric field of the guide or resonator at or near a point where the electric field has its maximum value. It is designed to transfer energy to or from the external circuit.

COUPLING, RESISTANCE-CAPACITANCE. A coupling method used in electronic amplifiers which employs resistance elements for the load impedance of the stages. A capacitor connects the output of one stage to the input of the next for a-c and transient signals without disturbing the d-c operating points of either stage. (See **circuit, coupling**.)

COUPLING, TRANSFORMER. Cascade, electronic-amplifier coupling in which the load impedance of one stage is the primary of a transformer whose secondary drives the grid of the succeeding stage. (See **circuit, coupling**.)

COVERAGE. The usable range of a radar set measured in all directions about the radar location. The coverage is a function of the characteristics of the system, including output power, receiver sensitivity, target size, and the presence of interference sources in the fields of view of the radar. (See also **antenna coverage pattern** and **clutter**.)

C_p . Coefficient of pressure (aerodynamics); specific heat at constant pressure.

CPFF. Cost plus fixed fee; refers to type of contract generally used to cover research and development.

C_R . Resultant force coefficient, aerodynamics.

Cr. Chromium.

CRAB ANGLE. The angle between the heading of an aerodynamically-supported body and its true course.

CRAFT. Specifically: (1) An aircraft, or aircraft collectively. (2) Any vehicle or machine designed to fly through air or space; also collective. (See **machine** and **vehicle**.)

CRATER. The pit, depression, or cavity formed in the surface of the earth by an explosion. The nearer to the surface the detonation occurs, the shallower the crater.

CRATER DEPTH. The maximum depth of a **crater** measured vertically from the deepest point of the pit to the original ground level.

CRATER DIAMETER. The average diameter of a **crater** measured at the level corresponding to the original surface of the ground.

CREEP. Plastic flow of a material under constant **stress**. At low temperatures the creep rate is usually low, the strain being often found to vary as the logarithm of the time, but the effect increases rather rapidly with temperature. The theory of creep is very incomplete.

CRESCCELERATION. Acceleration in powers of 10.

CREST FACTOR OF PULSE. Pulse, crest factor of.

CREST FACTOR OF A PULSE CARRIER. Pulse carrier, crest factor of.

CRIT. The mass of fissionable material which, under a given set of conditions, is **critical**. Sometimes applied to the mass of an untamped critical sphere of fissionable material.

CRITICAL. In nuclear reactor terminology, a reactor is said to be critical when it is capable of sustaining (at a constant level) a chain fission reaction (see **nuclear reaction**). It is said to be prompt critical when it can sustain the fission reaction without the aid of delayed neutrons (see **neutron, delayed**).

A mass of fissionable material is said to be

of critical size when it has reached a magnitude, and shape, by some assembly process or other means, sufficient to produce an explosive fission reaction.

CRITICAL AIR VELOCITY. (1) The air velocity at which compressibility effects must be considered in a particular system. (2) The limiting velocity of efflux of a fluid stream from a jet which cannot be increased by further decrease in external pressure.

CRITICAL ALTITUDE. Any altitude above which the performance of a flight vehicle, its passengers or one of its equipments falls off; above which some particular danger exists; above which some condition is encountered requiring special attention, etc., and therefore regarded as critical, as: (1) The maximum altitude at which a supercharger can maintain a pressure in the intake manifold of an engine equal to that existing without the supercharger at rated power and speed at sea level, or the maximum altitude at which any kind of propulsion system, such as that of a guided missile, can meet performance specifications. (2) An altitude above which harmful effects from cosmic radiation occur.

CRITICAL ANGLE. The minimum angle of incidence at boundaries between two media at which total reflection of light, or other electromagnetic radiation, occurs. Its value is given by the equation,

$$d = \arcsin n_2/n_1,$$

where d is the critical angle, n_2 is the index of refraction of radiation (of that frequency) in the incident medium, and n_1 is the index of refraction in the bounding medium.

CRITICAL ANGLE OF ATTACK. Angle of attack, critical.

CRITICAL COUPLING. In a tuned-primary, tuned-secondary transformer, the degree of **coupling** which causes the maximum secondary current. This condition also provides maximum flatness of the **passband**. If the primary and secondary are tuned to the same frequency, the condition for critical coupling is:

$$\omega M = \sqrt{R_p R_s}$$

where ω is the frequency in radians per second, M is the coefficient of coupling, and R_p

and R_s are primary and secondary resistances, respectively.

CRITICAL CYLINDER. In photogrammetry, the volume within which resection is likely to be in error. It is synonymous with "region of error."

CRITICAL DAMPING. Damping, critical.

CRITICAL DAMPING CONSTANT. Damping, critical constant.

CRITICAL ESCAPE ALTITUDE. The highest altitude at which a man without pressure suit or breathing gear can abandon his vehicle safely.

CRITICAL FIELD. (1) The magnetic field H_c below which the superconducting transition takes place at a given temperature. Empirically, a relation is observed of the form

$$H_c = H_0 \{1 - (T/T_c)^2\}$$

where H_0 is a parameter characteristic of the material, and T_c is the critical temperature of the superconductor. (2) Of a **magnetron**, the smallest theoretical value of steady, magnetic flux-density, at a steady anode voltage, that would prevent an electron, emitted from the cathode at zero velocity, from reaching the anode.

CRITICAL FREQUENCY (ELECTRO-MAGNETIC WAVE). (1) The limiting frequency below which a magneto-ionic wave component is reflected by, and above which it penetrates through, an **ionospheric layer** at vertical incidence. (2) In the propagation of any wave phenomena, a frequency which if exceeded will cause drastic changes in the continuity of propagation, as in a **band-pass filter**.

CRITICAL MACH NUMBER. (1) The value of the **Mach number** at which the flow becomes markedly turbulent. (2) The value of the Mach number of an airplane or space vehicle at which a Mach number of 1 is reached at any important local point on the airplane or space vehicle.

CRITICAL MATERIALS. A general classification of raw and processed materials according to their strategic value, both in time of peace (stockpiling) and in time of war.

CRITICAL MASS OR SIZE. In a fissionable material the amount of material which will just support a chain reaction power level. This is related, among other things, to the volume it occupies, or size.

CRITICAL OPERATION. A term which describes a limiting condition for ramjet operation. When the heat released by the burner is of such a magnitude that the back pressure at the exit to the subsonic diffuser causes the normal shock to be positioned at the inlet, then the operation is said to be "critical."

CRITICAL PRESSURE. (1) The pressure required to cause liquefaction of a gas at its critical temperature. (2) The external pressure below which gas flowing through an orifice will not increase its velocity of efflux.

CRITICAL PRESSURE RATIO. The ratio of the pressure at the minimum diameter of the throat of a jet to the **stagnation pressure** of the fluid being expelled. The term is applied only to cold flow conditions.

CRITICAL REYNOLDS NUMBER. The **Reynolds number** at which some significant change occurs, e.g., the Reynolds number at which a transition from laminar to turbulent flow begins, or at which the drag of a cylinder or sphere drops sharply.

CRITICAL TEMPERATURE. In thermodynamics, the temperature above which a gas cannot be liquefied by pressure alone. For air, this temperature is -140°C , for carbon dioxide it is 31.2°C .

CRITICAL VELOCITY OF FLOW. If above a certain velocity of flow the nature of the flow changes qualitatively, the velocity is critical for the particular flow system. The criterion is always better expressed as a critical **Reynolds number**, **Mach number**, or **Froude number**.

CRO. Cathode-ray oscilloscope.

CROSSBAND OPERATION. Operation of two parts of a system on frequencies that differ, usually sufficiently to interact usefully.

CROSSBOW. A USAF missile project carried on by Northrop Aviation. It was tested at Holloman Air Force Base. Radioplane is the prime contractor and Bendix produces

the control system which homes on enemy radar.

CROSS COUPLING (IN A TRANSMISSION MEDIUM). A measure of the undesired power transferred from one channel to another.

CROSS-HAIR LINES. Fine lines (spider web, silk, fine metal wire, fine lines on a flat glass plate) placed at the exact position of the first real image in a telescope or microscope for the purpose of aiding in pointing the instrument at a particular point of the object.

CROSS-MODULATION. Modulation of a desired signal by an undesired signal.

CROSSOVER FREQUENCY. (1) As applied to electric dividing networks, the frequency at which equal electric powers are delivered to each of the adjacent frequency channels when all channels are terminated in the loads specified. (2) The transition frequency in a two-channel loudspeaker system at which the low (woofer) and high (tweeter) frequency units deliver equal power.

CROSS POINTING, INITIAL. A change in orientation of a rocket normal to the launcher at the time of launching.

CROSS PLOT. In graphical presentation (e.g., data reduction), the linearized plot of one function versus another for comparison purposes.

CROSS POLARIZATION. The component of the electric field vector normal to the desired polarization component.

CROSS-TALK. The interference between nearby circuits, wherein signals in one circuit are undesirably reproduced in another, or other circuits.

CROSS VELOCITY, INITIAL. A change in the velocity of a rocket normal to the launcher, at the time of launching.

CROSS WIND. A wind which is at an angle to the flight path.

CROSS-WIND FORCE. In rocket ballistics, a term sometimes used for **pitching force**. It is a force acting perpendicular to the forces of lift and drag and is responsible for the tendency of a missile to **weathercock** upon launching.

CRT. Cathode ray tube.

CRUCIFORM GRAIN. A solid propellant rocket grain with a cruciform cross section. The grain is an external burning, partially restricted type.

CRT. Cathode ray tube.

CRUISE MISSILE. A U.S. Air Force term referring to an aerodynamic type missile, i.e., a missile which was formerly known as a "pilotless aircraft."

CRYOGENIC SYSTEM. A system in which a local temperature much lower than the surrounding temperature is produced.

CRYOGENICS. The science of physical phenomena in the temperature range below about -50°C (-58°F), although some usages restrict the term to the temperature range within a few degrees of **absolute zero**. More generally, cryogenics, or its synonym "cryogeny," refers also to methods of producing very low temperatures.

CRYOSTAT. A low-temperature thermostat.

CRYOTRON. A device developed at Massachusetts Institute of Technology by Dudley A. Buck and others. It utilizes for switching purposes the fact that the superconductive transition depends upon temperature as well as electromagnetic field. A straight wire is placed inside a coil of different material and cooled to its superconductive temperature. (This temperature varies with the material, but for tantalum is 4.38°K ., or close to 269 degrees below 0°C .; for niobium it is 9.22°K ., etc.) When the straight wire becomes superconducting, a very small voltage is sufficient to cause a persistent current to flow in it. If, however, another current passes through the coil, its surrounding magnetic field changes the superconductivity of the straight wire and the current in the latter ceases.

CRYSTAL. A macroscopic sample of a solid substance exhibiting some degree of geometrical regularity, or symmetry, or capable of showing these properties after suitable treatment (e.g., cleavage, etching, etc.). Almost all pure elements and compounds are capable of forming crystals.

A perfect crystal is one in which the crystal structure would be that of an ideal space lat-

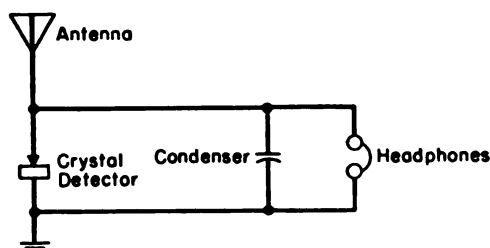
tice. No such crystals exist, all real crystals containing imperfections which have a strong influence on the physical properties of the crystal.

There are two types of crystals which are used in communications work, the rectifying and the piezo-electric. Among the first may be mentioned galena, germanium, silicon and silicon carbide. All have the property of passing current in one direction and not in the other, or in some cases unequally in the two directions. Since demodulation or **detection** in fundamentally a process of rectification these crystals may be used as detectors of modulated radio signals.

CRYSTAL-CONTROLLED OSCILLATOR. Oscillator, crystal controlled.

CRYSTAL-CONTROLLED TRANSMITTER. Transmitter, crystal-controlled.

CRYSTAL DETECTOR. A device consisting of a "cat's whisker" bearing on a semi-conducting crystal, used in early radio sets. It depends for its action on the rectifying properties of the point contact, just as in the type-A transistor. (See figure.)



Crystal used in a simple receiver.

CRYSTAL DIODE. Diode, crystal.

CRYSTAL FILTER. A highly selective tuning circuit employing a quartz crystal, sometimes used in the i-f amplifier of a communications receiver to improve selectivity so as to permit reception of a desired station, even when there is strong interference from other stations on nearby channels.

CRYSTAL, MIXED. A crystal consisting of two or more chemical compounds, which may have the same positive radical or the same negative radical, and which, in their pure form, are isomorphous, i.e., have the same crystal form.

CRYSTAL, MIXER. A crystal used in an electrical circuit to receive two signals of different frequencies and sum these to obtain a useful beat frequency.

CRYSTAL, PIEZOELECTRIC. A crystal of a substance having strong piezoelectric (see **piezo-effect**) properties cut in such a way that the coupling to some particular mechanical mode of the crystal is emphasized. Such crystals are valuable as electro-mechanical **transducers**, as in the crystal microphone. The sharpness of the mechanical resonance of a solid makes a crystal resonator one of the most stable of frequency standards when loosely coupled into an electronic circuit.

CRYSTAL RECTIFIER. Rectifier, crystal.

CRYSTAL, RESONANCE FREQUENCY OF. The frequency at which a **piezoid** has either a maximum or minimum impedance, depending upon whether parallel or series resonance is employed.

CRYSTAL VIDEO RECEIVER. In electronics, an r-f crystal diode detector and video amplifier usually followed by a cathode follower. It is a type of receiver used where weight and size or cost are of primary importance over superior sensitivity, fidelity and selectivity. The **sensitivity** of the best crystal video receiver is about 10^{-8} watt.

Cs. Cesium.

C-SCOPE. A **radarscope** that presents azimuth by deflection of the target signal along a horizontal scale, and elevation by deflection along a vertical scale.

CTV-N-9. The official designation for the U.S. Navy **Lark** missile.

Cu. Copper.

CUBICAL ANTENNA. Antenna, cubical.

CUMULATIVE DOSE (RADIATION). The total dose resulting from repeated exposures to radiation of the same region, or of the whole body.

CUMULONIMBUS. The thunderstorm cloud. It is tall, billowed, full of contrast from brilliant white to inky black. Most of the cloud is composed of water droplets but the top, which penetrates above the freezing

level is composed of ice crystals. False *cirrus* often develops at the top of anvil head. Cumulonimbus occur with bases from 500-15,000 feet and tops from 10,000-50,000 feet.

CUMULUS CLOUDS. Billowed heaps with flat bases and tufted tops. They have considerable shadow and often are very dark on the underside. Size and shape vary from flat small balls of cloud-cotton to great towers with valleys and ravines along the sides. The cloud is a low type, but can be found with bases from 500-1000 feet and tops as high as 20,000 feet. It is composed of water droplets and may produce rain if well developed. Flat, fair-weather types are known as *cumulus humilis* and the well-developed variety as *cumulus congestus*.

CURIE. A unit of radioactivity which was originally defined as the amount of emanation (radon) from or in equilibrium with one gram of radium. Because of experimental uncertainties this unit has been redefined by the revised recommendations of the International Commission on Radiological Units (July, 1953) as follows: "The curie is a unit of radioactivity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is 3.700×10^{10} ."

CURIUM. Transuranium radioactive element. Symbol Cm. Atomic number 96.

CURRENT AMPLIFICATION. (1) Of an amplifier, the ratio of the current produced in the output circuit as a result of the current supplied in the input circuit, to the current supplied to the input circuit. (2) Of a magnetic amplifier control-winding, the ratio of the change in output current to the change in current in the control winding required to produce the output current change. (3) Of a multiplier phototube, the ratio of the output current to the photocathode current due to photoelectric emission at constant electrode voltages. Terms output current and photocathode current as here used do not include dark current. This characteristic should be measured at levels of operation that will not cause saturation. (4) Of a transducer, the ratio of the magnitude of the current in a specified load impedance connected to a transducer to the magnitude of the current in the input circuit of the transducer. If the input and/or output current consist of more than

one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. By custom, this amplification is often expressed in decibels by multiplying its common logarithm by 20.

CURRENT ATTENUATION. Of a transducer, the ratio of the magnitude of the current in the input circuit of a transducer to the magnitude of the current in a specified load impedance connected to the transducer. If the input and/or output current consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting need to be specified. By custom, this attenuation is often expressed in decibels by multiplying its common logarithm by 20.

CURRENT, DIRECT. (1) A current through a specified surface, which does not change sign. (Note that current is a scalar.) (2) A steady current.

CURRENT, EDDY. The current which flows in a conductor as a result of flux linkage changes seen by that conductor. It is, in general, an undesirable effect, as opposed to the load current in the secondary of a transformer which is the result of flux linkage changes. Eddy currents contribute to the power losses in magnetic cores, conductive shields, and the conductors themselves.

CURRENT, EFFECTIVE OR ROOT-MEAN-SQUARE. The root-mean-square value of a current (I) over a time interval (t_1, t_2) is

$$\text{Rms } I = \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} I^2 dt \right]^{1/2}.$$

For a sinusoidal current, the rms value over any integral number of periods is $\sqrt{2}/2 \approx 0.707$ times the peak value. Since the power (e.g., heat in a resistor) depends on the square of the current, the rms value is frequently called the "effective value." The term "effective value" is deprecated in modern usage.

CURRENT, ELECTRIC. Broadly, the flow of electric charge. More specifically, the time rate at which charge crosses a given surface is the current across the surface. There are actually three types of current: conduction current, convection current, and displacement

current. Conduction current is due to the motion of charges in a neutral system (as **electrons** in a **conductor**, or the motion of electrons and "holes," which contribute largely to the current in **semiconductors**); convection current is due to the motion of unneutralized charge, as the motion of electrons in a vacuum tube; displacement current is an effect of a changing electric flux. Current is a scalar. The current through a specified surface is given by the integral over that surface of the normal component of **current density**. In loose usage, we often speak of the direction of a current; actually, being a scalar, current has a sense (plus or minus) but not a direction.

CURRENT FEED. The connection of the feed transmission line to the maximum current point in an antenna system.

CURRENT, GATE. The current through the gate winding of a **magnetic amplifier**. This current may be either a-c or pulsating d-c.

CURRENT, INDUCED. Current in a conductor due to the application of a time-varying electromagnetic field.

CURRENT, INSTANTANEOUS. The instantaneous value of a **current** which varies with time.

CURVATURE CORRECTION. In data reduction processes where highly accurate results are desired, or long distances are being covered by the missile, it is necessary to correct the Cartesian coordinate values which are used for position data. The curvature correction is based upon the fact that the horizontal plane at the origin of the coordinate system will be inclined at an angle to the horizontal at the impact point. The angular distance at the center of the earth corresponding to this planar divergence for the tilt of the two horizontal reference planes is exactly equal to the angle subtended by the target and launch point radii as measured at the center of the earth. In this curvature correction, the oblateness of the earth is disregarded, that is, the figure of the earth is assumed to be a perfect sphere.

CURVATURE OF FIELD. In optics, an aberration causing images to fall on a curved or dish-shaped surface.

CURVILINEAR MOTION OF A PARTICLE IN A PLANE. The differential equations of motion of a particle of mass m in a plane are (in rectangular coordinates):

$$m\ddot{x} = F_x$$

$$m\ddot{y} = F_y$$

where F_x and F_y are the components of the resultant force acting on the particle. The solutions of these equations give the parametric equations for the motion of the particle. The motion of a projectile, the motion of the planets around the sun and the composition of two perpendicular simple harmonic motions are examples of this type of motion.

CUTOFF. (1) A particular point in a cycle, or magnitude of a quantity, at which a mechanism, electric circuit, or other system, cuts off some flow to or from it. Thus, the steam engine cutoff is that percentage of stroke accomplished by the piston, when the inlet valve closes and prevents more steam entering the cycle from the boiler. The cutoff of a Diesel cycle is the fraction of the stroke accomplished when supply of fuel oil to the cylinder is stopped. In electronic usage, the word cutoff often appears as a contraction for **cutoff frequency**. (2) The intentional termination of thrust from a rocket motor in flight (verb). (3) The occurrence or time of cessation of motor burning. Cutoff is used as a means of range control in some types of **ballistic missiles**. As the velocity of the missile increases, cutoff becomes a difficult problem, since a perfectly precise termination is impossible. The thrust **decays** at an appreciable rate, and where high accuracy is desired at great ranges, any unpredictable decay time is not permissible. Some missiles use a "vernier" cutoff in which the main thrust is reduced slowly and uniformly before final cessation, and a smaller motor takes over for the critical cutoff phase. This motor operates at a much lower thrust, and its decay transient has less effect on range. Another method of using cutoff for range control is to learn the thrust decay characteristics and insure their reproducibility in flight, so that accuracy can be obtained. (4) A technique used in theoretical physics when the theoretical contribution to the value of a physical quantity arising from integration over part of the range of a certain parameter is not to be believed, in particular when such a contribu-

tion is infinite. The integral is cut off, usually at some high frequency limit, with the acknowledgment that beyond this limit either the method of approximation, or the theory itself, will have to be modified in the future. (See also **brennschluss**.)

CUTOFF ANGLE. The angle between the tangent to the trajectory and the vertical at the power cutoff point. It is sometimes called the "angle of departure."

CUTOFF BIAS. The voltage which must be applied to the grid in order to stop the flow of anode or plate current in a vacuum tube. It is a valuable reference point in the discussion of vacuum tube characteristics as much of the tube behavior is determined by where the bias voltage is set with respect to the cutoff value. (See **cutoff**, **voltage**.)

CUTOFF FREQUENCY (CUTOFF). (1) Of a **transducer**, either a theoretical cutoff frequency or an effective cutoff frequency. (2) Of a **wave filter**, the frequency at which the attenuation begins to increase sharply. In the ideal filter, the attenuation would go to infinity at the cutoff frequency, but in a practical filter the rise in attenuation is not so abrupt, and never reaches infinity, but does usually go to a very high value. (3) For a given transmission mode in a non-dissipative, uniconductor waveguide, the frequency below which the propagation constant is real.

CUTOFF FREQUENCY, EFFECTIVE (EFFECTIVE CUTOFF). A frequency at which the insertion loss of a **transducer** between specified terminating impedances exceeds by some specified amount the loss at some reference point in the transmission band.

CUTOFF POINT. That point in the trajectory of a missile at which **cutoff** takes place.

CUTOFF VELOCITY. The velocity of a missile at the instant of **cutoff**.

CUTOFF, VOLTAGE. Of an **electron tube**, that electrode voltage which reduces the value of the dependent variable of an electron-tube characteristic to a specified low value. A specific cutoff characteristic should be identified as follows: current versus grid cutoff voltage, spot brightness versus grid cutoff voltage, etc.

CUTOFF, WAVELENGTH. Of a uniconductor **waveguide**, the ratio of the velocity

of **electromagnetic waves** in free space to the **cutoff frequency**.

CUTTER (CUTTING HEAD). An electro-mechanical transducer (see **transducer**, **electromechanical**) which transforms an electric input into a mechanical output, typified by mechanical motions which may be inscribed into a recording medium by a cutting stylus.

C_v. Coefficient of velocity; specific heat at constant volume.

CW. Continuous wave.

CW DOPPLER RADAR. A radar which uses continuous waves (as distinct from pulsed radiation) and the **Doppler** shift to perform its function. If the target is stationary, its presence may be detected by rectifying the energy returned from the target and displaying it upon a d-c galvanometer. No other property of the target may be deduced except its presence and possibly its direction. If, however, the target is moving, its **radial velocity** also may be detected by comparing the echo frequency against the transmitted frequency. The echo radio frequency will differ from the transmitted frequency because of the Doppler effect. (See also **CW Radar**.)

C_x. Longitudinal force coefficient (aerodynamics).

CYCLE. (1) The complete sequence of values of a periodic quantity which occur during a period. (2) A series of changes executed in orderly sequence, by means of which a mechanism, a working substance, or a system is caused periodically to return to the same initial condition, constitutes a cycle. Many complicated machines or assemblages of machines work in definite cycles. An important form of cycle is the heat-engine cycle, in which a series of thermodynamic changes in a working medium periodically return the system to the same thermodynamic level.

CYCLIC BINARY CODE. Gray Code.

CYCLIC SHIFT. In computer terminology, an operation which produces a word whose characters are obtained by a cyclic permutation of the characters of a given word.

CYCLING. A periodic change of the controlled variable in an **automatic controller**.

CYCLOGYRO. Helicopter.

CYCLONE. A wind system around low atmospheric pressure. If a barometric depression is sufficiently low to be classed as a cyclone, it develops or has associated with it winds which flow around its center counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere. The intensity of a cyclone depends on the **pressure gradient** between the system's center and periphery, and on the characteristics of the air masses involved. Cyclones are divided into two groups.

(1) Tropical cyclones are vortices with indefinite or short-lived frontal structures which occur over the tropical and subtropical regions, particularly over the western half of the Atlantic and Pacific and over the Indian Ocean. They are known as hurricanes, typhoons, and baguios.

(2) Extra-tropical or wave cyclones are composed during development, youth and maturity of definite parts including warm and cold sectors and warm and cold fronts, but beyond maturity approach vortex structure. Nearly all the storms of the temperate zone are wave cyclones.

CYCLONITE. A high explosive $(\text{CH}_2)_3\text{N}_3(\text{NO}_2)_3$. It is also called *RDX*.

CYCLOSTROPHIC WIND. A wind which blows as a result of a pressure gradient and centrifugal force, but in the absence of **Coriolis force**. It is, of necessity, cyclonic and restricted to equatorial zones, which are the only places where Coriolis force is zero. The cyclostrophic component of a wind is the difference between the gradient and the **geostrophic** winds. Hurricanes are largely cyclostrophic winds until they travel north or south sufficiently to be affected by Coriolis force.

CYGNUS. (The swan.) Cygnus is one of the most striking and interesting **constellations** of the northern sky. It represents a swan flying with outstretched wings and legs trailing out behind. It is also frequently referred to as the northern cross. Lying, as it does, in one of the most impressive portions of the northern **milky way**, the constellation contains many interesting objects. The brightest star (alpha Cygni) known as Deneb, is one of the most distant of all of the bright stars; its intrinsic

brightness being about 1000 times that of the sun. Beta Cygni is one of the most striking of all of the **double stars**, both components being bright, one blue and the other orange, and easily separated by a small telescope. No physical connection has been determined between the components and it probably is not a true **binary**. Another interesting member of this constellation is the relatively faint star, marked 61 on large star maps. This is the first star whose distance was measured in 1838 by the astronomer Bessel. Bessel's determination of the **stellar parallax** of this object opened a field of astronomic research which has done much to solve many of the problems of general cosmogony.

CYTAC (LORAN-C). A system of determining hyperbolic **lines of position** by measuring the time relationship between two synchronized radio signals. CYTAC is similar to **loran** in principle but capable of greater accuracy and has a greater range of operation since it utilizes only the ground wave at 100 Kc. Cycle matching is used for maximum accuracy.

C_z. Normal force coefficient (aerodynamics).

CZR. A type of **ballistic camera**. The camera is a development of the original Bowen RC-2 ribbon frame camera made for the Naval Ordnance Test Station at Inyokern, California. The CZR-1 has a precision 3-axis mount, allowing flexibility to the camera orientation, and thus permitting a wide variety of instrument geometry. It is similar to the RC-2 in respect to frame configuration, film used, type of shutter, range of frame speeds, and use of reference crosses. However, the accuracy of the CZR-1 is improved over the RC-2 by an improved lens mount, a star projector for correcting for changes in the focal length of the lens, and an improved timing system. Binary timing marks are shown on the edge of the frame. Exposure time can be varied from 1/10,000 to 1/50,000 second. The CZR-1 mount also permits measurements around three adjustable axes. The CZR-1 has 18-second accuracy in the mount so it can define the absolute position of a missile in space within 3-4 feet when the camera is used at normal operating distances (generally from 1500 to 2500 feet off range), and it can define velocity within 14 feet per second.

D

D. (1) Mass per unit volume or density (R , but ρ is preferred). (2) Density of electric flux (**D**). (3) Optical density or absorbence (D). (4) Diameter (d or D). (5) Dielectric flux density (**D**). (6) Coefficient of fluid diffusion (D). (7) Dioptric power (**D**). (8) Angular dispersion (D). (9) Electric displacement (**D**). (10) Displacement flux density (**D**). (11) Deuterium (**D**). (12) Dextrorotatory d - or d -). (13) Differential (followed by another letter or letters) (d). (14) Bulk density (propulsion) (d). (15) Web thickness (propulsion) (d). (16) Drag (aerodynamics) (D).

D LAYER. The lowest layer of the **ionosphere**. This layer, occurring between 25 and 50 miles above the earth's surface, and exhibiting a maximum of ionization 35 to 40 miles above the earth's surface, absorbs some of the radio energy reflected by the E and F layers. (See also **atmosphere**.)

D REGION. The region of the **ionosphere** up to about 90 kilometers above the earth's surface. (See also **atmosphere**.)

DAF. Department of the Air Force.

DABBLE. A process in the mathematics of binary numbers in which the binary number is doubled and the digit one (1) added to the resultant. For example, to evaluate the binary number 011100 (i.e., to convert it to decimal form):

0	1	1	1	0	0
1	(1×2)+1	(3×2)+1	(7×2)	(14×2)	
3	7	14	28		
(dabble)	(dabble)	(double)	(double)		

The rule is to double when the next digit is 0 (next referring to the next higher order), and to dabble if the previous higher digit is 1, i.e., to double and add 1. (See also **binary**.)

DALTON LAW. If several gases not reacting chemically upon each other are introduced

into the same container, the pressure of the resulting mixture is equal to the sum of the pressures which would be observed if each gas were separately enclosed in that container. Like other gas laws, this law is approximately valid only within limits. It holds universally for ideal gases.

DAMAGE AGENT. An explosive carried within a warhead to be released against an enemy target to cause the desired damage.

DAMAGE CONTROL. The means for controlling damage at a launching site or aboard ship incident to inadvertent missile explosion or action.

DAMAGE VOLUME OF MISSILE. Envelope of swept-out volume defined by the range-limits of the destructive agent carried by a missile.

DAMPED WAVES. Waves, damped.

DAMPING. In general, the checking of a motion by resistance, as by friction. It is of especial significance in connection with the diminishing amplitude of an **oscillation**, as that of a pendulum swinging in the air, or that of the electricity vibration in an oscillating circuit. Unless energy is supplied during each cycle, the amplitude of such a vibrator falls off at each successive oscillation by an amount commonly expressed in terms of the decrement, or damping factor, which is the ratio of any one amplitude to that next succeeding it in the same sense or direction.

In so-called logarithmic damping, this decrement is constant; in a simple oscillating electric unit, the amplitude decays as $e^{-\delta t}$; where t is the time and δ , the logarithmic decrement, is a constant depending upon the effective resistance, inductance, and capacitance of the circuit. (See **electric oscillations and waves**.) In missile control, fin surfaces are frequently actuated by an oscillatory signal so that the surface first undergoes a desired displacement and then returns in the

opposite direction. The signal necessary to accomplish this movement may start the system oscillating unless the fin is damped either by frictional devices, or by electrical signals to the servo system.

DAMPING, AERODYNAMIC. Aerodynamic damping.

DAMPING, COULOMB. Damping, dry friction.

DAMPING, CRITICAL. (1) In an elastic mechanical system subjected to a periodic force, the amount of damping just sufficient to prevent vibration from occurring if the system is displaced and then released. It is expressed by the relationship:

$$C_c = 2\sqrt{km} = 2m\omega_n,$$

where k is the spring constant, m is the mass, and ω_n is the circular natural frequency. (2) The threshold value of damping which will just prevent oscillation in an electrical system subjected to a periodic forcing function.

DAMPING DECREMENT. Logarithmic decrement.

DAMPING, DRY FRICTION. The damping in a mechanical system resulting primarily from friction forces which are independent of velocity or displacement. The damping force is equal to the coefficient of friction times the normal force.

DAMPING, OPTIMAL. That value of damping, with the damping ratio slightly less than unity, at which an indicating system such as a galvanometer will overshoot its final deflection by less than the desired uncertainty in reading the instrument. In general, optional damping results in faster readings than does critical damping, with no real loss in accuracy.

DAMPING RATIO (VISCOUS DAMPING RATIO). The ratio of the actual damping coefficient for an oscillating mechanical system to the coefficient for a critically damped system. It is expressed by the relationship:

$$\frac{f_d}{f} = \sqrt{1 - \left(\frac{c}{c_c}\right)^2}$$

where f_d is the damped natural frequency, cps, f is the undamped natural frequency, cps, and $\frac{c}{c_c}$ is the damping ratio.

DAMPING, STRUCTURAL. Damping caused by structural impedance in an oscillating mechanical system. It is expressed by the relationship:

$$C = \frac{F}{e_F} \left(\frac{X_F}{X_o} \right)^2 = 2 \frac{c}{c_c},$$

where c is the damping coefficient, c_c is the critical damping coefficient, F is the force, e_F is the velocity of the force, X_F is the displacement of the force, X_o is the zero frequency deflection, and $2 \frac{c}{c_c}$ is the structural damping.

DAMPING TUBE. In electromagnetic-deflection, **cathode-ray tubes**, a tube used with magnetic deflecting-coils to prevent any transient oscillations from being set up in the tube or its associated circuits.

DAMPING, VISCOUS. The damping in a mechanical system in which the force varies in proportion to the velocity. The viscous-damping coefficient is equal to the ratio of the viscous-damping force to the velocity.

DAN. Deacon and Nike. A National Advisory Committee for Aviation project conducted for the U.S. Air Force Cambridge Research Center by NACA's Langley Aeronautical Laboratory. It consists of a two stage missile composed of a Nike booster and a Deacon solid propellant rocket. This combination was able to attain 73-92 miles altitude with 60-10 pounds of payload (the lesser payload reaching the greater height). Maximum velocity attained was Mach 5.8 (3,800 mph) during a time of flight of 5.6 minutes. Firings were conducted at Wallops Island, Virginia, during 1956. Total weight of the DAN combination was 224 pounds. It was designed to fit into a station wagon. Assembled it was 15 feet long and 6½ inches in diameter. It has been used for cosmic radiation, temperature and acceleration studies. In use the first stage reaches 10,000 feet altitude and 1,900 miles per hour. The second stage reaches 3,800 mph at 40,000 feet and then coasts on to the peak altitude.

DARK ADAPTATION. The sensitivity of the eye gradually decreases as the eye is exposed to increasing brightness. Eyes exposed to no light or to only faint red light become more sensitive as they become more "dark adapted."

DART. A U.S. Army solid-propellant, short-range, assault, demolition, or antitank rocket missile developed by the Aerophysics Development Corporation for the Army Ordnance Corps. Its design was based upon an earlier French (SNCA du Nord), development which in turn came from a German World War II design. Its development began in the United States in 1953, with the airframe by Utica-Bend, motor by Grand Central, optical tracking wire guidance by Wagner. Its design range was 1-2,000 yards at more than 900 feet per second speed. Its dimensions: length 5 feet, diameter 8 inches, wingspan 3 feet. The Dart configuration used 4 cruciform and slightly tapered rectangular wings mounted vertically and horizontally at mid-body. Four similarly-shaped tail surfaces were used at the rear, 45 degrees out of the wing track. The Dart was also designated XSSM-A-23 during its development phase. (See **missile, guided.**) (See also illustration facing Page 122.)

DASH POT. A mechanical damping device consisting of a chamber containing oil, air, or other fluid, and holding a plunger or pierced vane, that is connected in turn to a part or mechanism that is subject to rapid changes in position. The function of the dash pot is to slow these changes, by the resistance of its fluid to the motion of the plunger.

DATA. In guided missile research and development, information in any form which can be used to evaluate the performance of the developmental item. Data are not limited to simple trajectory information (i.e., space position, velocity, acceleration and attitude), but may involve quantities such as motor chamber temperature, pressure in fuel containers, angle-of-attack, and so forth. Data may be recorded in tabular form, graphical form, punched cards, paper tape, magnetic tape, oscillograph recordings, photographic film, radar plots, pencil notes or an infinity of other forms. The collection and processing of data is the heart of the research and development effort.

Raw data comprise the unprocessed information, e.g., direction cosines obtained from theodolite readings, photogrammetric records on camera films, or the films themselves. Unlinearized telemetric oscillograms could also be called raw data. When the transformations, conversions, corrections, computations and

other manipulations have been applied to the raw data to correct their values in magnitude and sense and put them into form for analysis, the results are called *reduced data*. The unprocessed or raw data consist of the measurements taken from the data collecting devices. Reduced data, taken from the reduction facility in an incomplete or unchecked status are called *preliminary data*. Data completely checked and published in finished form corrected for all known errors are called *final data*. Reduced data in a form suitable for evaluation are called *primary data*.

DATA ACQUISITION. That phase of data handling associated with obtaining, measuring and/or recording the basic parameter(s) to be measured: e.g., telemetering transducers are part of the data acquisition system.

DATA ANALYSIS. The logical, statistical and mathematical processes applied to the primary data to yield conclusions about the functioning of a system, such as a guided missile. From the primary data many performance characteristics of the missile can be deduced or inferred. For example, missile position data can be differentiated with respect to time to give velocity and acceleration, and the acceleration data can, in turn, give information on the thrust of the engine. The characteristics of the acceleration curve can indicate the uniformity of the rate of burning of the propellant. Data on the attitude of the missile while passing through the transonic range can give information on the stability of the configuration.

DATA HANDLING SYSTEM. Automatically operated equipment engineered to simplify the use and interpretation of the mass of data gathered by modern instrument installations. (See **data reduction.**)

DATA REDUCTION. The process of translating recorded information into meaningful form, e.g., into curves or tables showing variations of physical performance quantities occurring during the flight of a missile. Data reduction involves the extraction of raw data from the storage medium (magnetic tapes, photographic films, oscillograms, etc.), the performance of mathematical operations on this raw data, the checking of results, the printing, plotting, and publication of the final data with all necessary corrections to elimi-

nate systematic, operational, geodetic, instrumental, and other calculable errors. Depending upon the type of raw data being used, reduction is a process of physical as well as logical manipulation. In some instances the processes are complex and time consuming. Whatever their nature, the usability of the final data is completely dependent upon the reduction process. Each type of data collection system requires a different reduction routine. A short discussion of the more common data reduction processes follows.

Optical Data Reduction. The process of transforming timed photographs of a missile into tabulated or graphical position, velocity, acceleration and sometimes attitude data. The reduction process includes the developing and chemical processing of films, interpretation (i.e., read-out of raw data), computation, and presentation in desired form (i.e., in proper coordinate system and units), and in the physical arrangement (i.e., tabular or graphical), and preparation of duplicate copies. Optical data are obtained from photogrammetric camera film exposed at one or more stations of a known-base intersecting system. Successive positions of the missile are correlated in time on the two or more camera films. Azimuth and elevation angles to these positions are determined. From these angles, the time correlation, and the data collection geometry, a mathematical routine is established to yield the successive space coordinates of the missile. Further mathematical manipulation of these successive space positions give velocity and acceleration data. The mathematical routine used in the reduction process depends upon the types of computers, the coordinate system, the desired precision and accuracy, and the corrections to be applied. Highly accurate data are corrected for curvature of the earth between instrument sites, for atmospheric effects, for instrumental errors, for observational errors, and for other systematic errors.

DOVAP Data Reduction. DOVAP Data, which may be recorded on magnetic tapes, motion picture film or other media, consists of Doppler beats at a number of widely-spaced receiver stations. The frequency of the beats is proportional to the velocity of the missile in a line directly away from that station. Thus, three or more DOVAP stations are required for position determination, and the calculations of the trajectory positions require

finding the intersection of three (or more) ellipsoids in space. Each of these ellipsoids has a DOVAP receiver station as one focus, and the ground transmitter station as the other. Four or more stations are desirable for the attainment of greatest accuracy. The reduction process consists of counting the total number of beats received at any one station up to a given time of flight. On film this can be done visually or by means of an automatic photoelectric counter. On magnetic tape it is done by an electronic counter. The beats so determined are then used as coefficients in equations of the ellipsoids. These equations are solved simultaneously by machine computation to yield the point of intersection.

Radar Data Reduction. The basic problem of computation with radar data is the conversion of positions given in spherical coordinates to the corresponding values in a system of rectangular coordinates. The raw data may be recorded on punched type, which can be introduced directly into computing machines without further transformation. A further refinement is the use of a "boresight" camera which takes pictures of the missile in flight (while it is visible) through a hole in the radar dish. Additional corrections are made for orientation errors, for errors in level of the radar set, and to transform the coordinate origin from the radar position to the desired origin for the reduced data. Velocity of the missile is calculated from the difference of missile position along the trajectory but is usually not accurate.

Telemetry Data Reduction. Telemetry data are normally recorded on magnetic tape. They can be presented in two forms, "raw" and "linearized," the terms referring to data at two stages. In the reduction process, the magnetic tape is played into a frequency discriminator to isolate the frequencies, which carry information. In the standard Dept. of Defense FM-FM telemetry set, a total of 16 telemetry subcarrier channels are superimposed on the one FM carrier. One or several of these subcarriers may be commutated to carry up to 27 functions, each of which is sampled every 10th second. The commutated channels must be passed through a ground decommutator to extract the information. The straight channels (and the decommutated channels) may be converted from varying frequencies to varying d-c voltages, which then actuate light-beam galvanometers within a

multi-channel recording oscillograph. The oscillograph draws static reference lines and perpendicular timing lines over the data being played into them. When developed, the missile function shows as a varying black line trace on the oscillogram. This trace is called "raw" data, because the errors of telemetry system have not yet been corrected. When the known errors are removed the oscillograph-recorded data are said to be "linearized." The linearization process consists of correcting the raw data for (1) the errors of the end instruments used in the missile and (2) the errors of drift natural to the electronic transmission and recording system. Both (1) and (2) are accomplished by application of calibration curves to the raw data. In the linearization process, one calibration curve, a composite of all known systematic errors, is used. The telemetry channel errors are determined during flight by the periodic transmission to the ground of decoded stepsignals (10-20-30 etc. through 100%) of maximum d-c voltage applied to modulate the missile transmitter. Inflight calibrations are used to draw the telemetry channel calibration curve. (See also **linearization**, **oscillograph**, **quick look**, **real time telemetering**, **timing**, and **FM-FM**.)

DATATRON. A digital computer installed at the Ames Aeronautical Laboratory, Moffitt Field, California. It was manufactured by the Electrodata Corporation.

DATA CONVERTER. A device for changing the form of data, for example, for converting angles of elevation to proportional voltages.

DAWN AND DUSK ROCKET. In space travel, rocket vehicles might be fired either at dawn or dusk in order not to be adversely affected by the rotational motion of the earth. In a solar reference system, a daylight takeoff will cause the earth's rotational velocity to be subtracted from its orbital velocity; conversely at night these velocities are additive. Accordingly there is an optimum time of takeoff depending upon the mission.

DAY. A measure of time based upon the rotation of the earth with respect to either the vernal equinox (sidereal day), or the sun (solar day). The *apparent solar day* is the interval of time from a transit of the sun across a given meridian to its next successive transit across the same meridian. Since the

motion of the sun is not uniform, apparent solar days vary in length through the year. The maximum deviation from a mean solar day amounts to about half a minute in either direction. The *astronomical day* is a solar day beginning at noon. The *civil day* is a solar day beginning at midnight. The *mean solar day* is the interval of time from a transit of the true vernal equinox across a given meridian to its next successive transit across the same meridian. The *solar day* is the interval of time from the transit of either the sun or the mean sun across a given meridian to the next successive transit of the same body across the same meridian. The *sidereal day* is also defined as the interval between two successive transits of the first point of Aries over the upper meridian of any place. It is equal to 23 hours 56 minutes 4.09 seconds of mean solar time. It is also called the *star day*.

db. Decibel.

DBM. Power level or signal strength in decibels with reference to a power of one milliwatt (0.001 watt).

D-C. Direct current.

D-C AMPLIFIER. A direct coupled amplifier, which is used as an **isolation circuit**, summing device (to add direct current voltages) and for **coupling**. It is widely employed in computing circuits as an operational amplifier to accomplish specific mathematical operations. It is an inherently unstable circuit, having a very high **gain**.

DCO. Development Contract Office—Development Contract Officer.

D-C RESTORER. A device which **clamps** either the positive or negative peak value of a **waveform** to some desired level. In television receivers the waveform is clamped at the pedestal level, thus effectively restoring the black level established at the studio.

DEACON. A small solid propellant rocket produced by the Allegheny Ballistics Laboratory for high altitude research. The Deacon was used in 1952-53 in the Rockoon combination with Skyhook balloons. At that time it was about 12 feet long, 6½ inches in diameter at the body, with an enlarged conical nose of about 8 inches diameter which carried a 30

pound payload. Its fin span was 27 inches and bare weight 151 pounds. The Deacon was fired in the Rockoon tests at about 50,000 feet altitude from a sling launcher hanging some 100 feet below the Skyhook balloon. Firing was by a barometric pressure switch plus a timer. Since winds aloft kept the balloon ahead of the rocket hanging below, the rocket seldom struck the bag. In the Rockoon experiments altitudes of 50 miles were reached. The ground-launch maximum altitude for the Deacon was about 100,000 feet. (See illustration facing Page 123.)

DEAD BAND. (1) In general, the range of values through which the measured variable which is the input to a servo system or **automatic controller** can be varied without initiating effective response. (2) In a **magnetic amplifier**, a region of input signal change which causes no change in the output.

DEAD RECKONING. The navigation process used to obtain the approximate position of a vehicle by integrating estimates of velocity, direction, wind, current, etc. over the period of time since the last established fix (known position).

DEAD SPACE. In a hydraulic transfer valve, the range of input currents around null (zero load flow) where the load flow of the valve remains essentially zero.

DEAD SPOT. (1) A location in which radio reception over some band of frequencies is weak or non-existent. (2) A spot on a receiver dial which has poor or no **sensitivity**, due to improper receiver design.

DEAD TIME. An interval following response to one signal or event during which a system is unable to respond to another.

DEAD ZONE. Dead band.

DEBUNCHING. The action of forces of mutual repulsion between electrons causing the bunches of electrons to spread, both laterally and longitudinally.

DECABORANE. A chemical compound of the formula $B_{10}H_{14}$, useful in **high energy fuels**.

DECALAGE. The difference between the angular settings of the wings of a biplane.

DECAY. (1) The decomposition of radioactive materials. Decay is usually measured in terms of **half-life** of the material, i.e., the length of time for the radioactivity to decrease to one-half its original value. (2) Thrust decay is the non-instantaneous decrease in delivered thrust as a rocket motor is shut off. Thrust decay is an important factor in the range control of ballistic missiles. Since the rocket motor thrust does not drop to zero instantaneously, fine control of range depends upon an accurate knowledge or control of the motor thrust decay. (3) In acoustics, the time rate at which the sound pressure level (or velocity level, or sound energy density level) decreases at a given point at a given time. The practical unit is the decibel per second.

DECAY LAW, RADIOACTIVE. The exponential law

$$N = N_0 e^{-\lambda t}$$

which governs the decrease with time of the number of atoms of a radioactive species, provided the number is large. In the above equation, N is the number of atoms present at time t , N_0 is the number of atoms present at time zero and λ is the decay constant. The decay law is a statistical law so that if N is the number of radioactive atoms present, the number of which will disintegrate on the average in unit time is λN . The number which will disintegrate in any particular unit of time may not be exactly λN , but if a large number of measurements of the number of disintegrations per unit time is made, the values will show a Poisson distribution with λN as the average value.

DECAY MODULUS. In a damped harmonic oscillator, the time for the amplitude of oscillation to diminish $1/e$ of its initial value is called the decay modulus. For an oscillator with the equation of motion.

$$m\ddot{x} + R\dot{x} + fx = 0$$

the decay modulus is $2m/R$. (See **oscillation, damped**.)

DECAY, RADIOACTIVE. (1) Radioactive disintegration (see **radioactivity**). (2) The decrease with time of the number of radioactive atoms in a sample, because of their spontaneous transformation.

DECCA. A system of air navigation using transmitted continuous wave radio pulses based on a hyperbolic position-finding principle. The difference in time of reception of a primary transmitted signal and a signal from a synchronized secondary station is used to determine a line of position. The master transmitter station operates with two or more slave stations, thus enabling the establishment of two or more lines of position as needed for a fix. The receiver in the airborne vehicle measures the relative phase difference between the signals received from two or more of the synchronized ground stations. (See also **LORAN** and **Navigation**.)

DECELERATION. Negative **acceleration**.

DECELERATOR. Any device for slowing down a moving object.

DECEPTION, ELECTRONIC. The radiation or reradiation of electromagnetic energy in a manner intended to mislead the enemy in the interpretation of data received by his electronic equipment.

DECEPTION, IMITATIVE. The transmission of messages in the enemy's communication or radar channels with the intention of deceiving him.

DECEPTION, MANIPULATIVE. The manipulation of traffic in friendly communication channels with the intention of deceiving the enemy.

DECEPTION MEACONING. **Meaconing**.

DECEPTION, RADIO. Radio deception is the employment of radio to deceive the enemy; it includes sending false dispatches, using deceptive headings, employing enemy call signals, etc.

DECIBEL (DB). A unit for expressing the magnitude of a change in sound or electrical power level. One "db" is approximately the amount that the power of a pure sine wave sound must be changed in order for the change to be just barely detectable by the average human ear. The bel is the fundamental division of a logarithmic scale expressing the ratio of two amounts of power, the number of bels denoting such a ratio being the logarithm to the base ten of this ratio. The decibel is one-tenth of a bel. For example, with P_1 and

P_2 designating two amounts of power and n the number of decibels denoting their ratio

$$n = 10 \log_{10} \frac{P_1}{P_2}, \text{ decibels}$$

When the conditions are such that ratios of voltages or ratios of currents (or analogous quantities such as force or velocities, torques or angular velocities, pressures or volume currents) are the square roots of the corresponding power ratios, the number of decibels by which the corresponding powers differ is expressed by the following formulas:

$$n = 20 \log_{10} \frac{i_1}{i_2}, \text{ decibels}$$

$$n = 20 \log_{10} \frac{e_1}{e_2}, \text{ decibels}$$

where i_1/i_2 and e_1/e_2 are the given current and voltage ratios respectively. A common reference level is zero "db" with one milliwatt into a 600 ohm load; and sometimes 10^{-16} watts/sq. cm. pressure.

DECIBEL-MILLIWATT. A unit of power level usually abbreviated dbm. It is the power level in decibels with reference to a power of one milliwatt.

DECINEPER. One-tenth of a **neper**.

DECK MOTION PREDICTOR. A device to predict at given intervals and at a time prior to missile firing, ship's motion about its fore and aft and athwartship's axes in such a manner as to permit firing a missile at a desired condition of ship's attitude and motion.

DECLINATION. (1) In astronomy and celestial navigation, the angular distance of a celestial body from the **celestial equator** measured through 90° and named "north" or "south" as the body is north or south of the celestial equator measured on an hour circle. (2) *Magnetic declination* is the angle between geographic north and magnetic north. (3) *Grid declination* (also called gisement) is the angle between geographic north and grid north. (4) In geometry, the angle at the origin between a line of interest and a reference line. (5) In a system of polar or spherical coordinates, the angle at the origin between a line to a point and the equator, measured in a plane perpendicular to the equator. It is also the arc between the point and the

equator measured on a great circle perpendicular to the equator.

DECODER. (1) A device for the detection and interpretation of a pulse-code modulated signal. (2) A device, usually in the airborne portion of the guidance system, which accepts only properly coded guidance and command signals. (Coding is used to avoid enemy and friendly jamming, increase traffic handling capacity and permit increased data transmission on one link.)

DECODER, DIGITAL-ANALOG. A device for converting information available in digital form into a form suitable for utilization by an analog device. (Encoders are used to convert data from analog to digital form.)

DECOMMUTATION. The process of recovering an individual signal from a composite signal which has resulted from a process of commutation.

DECOMPOSITION IN STORAGE. An undesirable characteristic of some solid propellants. It is relatively common with double-base propellants, where it is often an autocatalytic process. An additive (diphenylamine) is sometimes used with such propellants to neutralize the catalytic effect of the initial decomposition products. In some instances the decomposition reaction is accelerated at higher temperatures, so that cool storage is indicated. A decomposed propellant may explode upon ignition; in aggravated cases it may ignite spontaneously.

DECONTAMINATION. Removal of radioactive materials.

DECOY. A countermeasure device intended to divert a guided missile or other weapon from its proper target.

DECREMETER. A device for measuring decrements or decreases in value of electrical quantities, e.g., the damping of an electric current.

DEEP SPACE. Inter-galactic space. The space existing beyond the solar system.

DEEP WATER BURST. An underwater nuclear burst in which the center of detonation is at a depth of at least 1000 ft.

DEFECT. (1) A faulty part in a missile or its ancillary equipment which will cause a failure. (2) A term used to include various types of point imperfections in solids, such as vacancies, interstitial atoms, etc., as distinct from extended imperfections such as dislocations. Lattice defects are particularly important in ionic crystals, where they may be created by heating in the vapor of one constituent, thus creating a stoichiometric excess, by bombardment with x-rays and energetic particles, etc. Any crystal must contain a certain equilibrium concentration of defects, as a function of the temperature, purely as a result of thermal agitation. Defects are responsible for the diffusion of ions, ionic conductivity, and the complex phenomena related to color centers.

DEFENSIVE FIREPOWER. The capacity of a target to inflict damage on an attacker.

DEFENSIVE MISSILE. A missile used to thwart an enemy attack which is proceeding against friendly forces or resources. In contradistinction, an offensive missile is used to destroy enemy forces or resources which could be employed at a later time.

DEFINITE CORRECTION SERVOMECHANISM. A servomechanism in which the power on the motor is controlled in finite steps at definite time intervals. (See also **servomechanism**.)

DEFINITION. In electronics or optics, the distinctness or clarity of detail or outline of an image. The units of definition are merely qualitative, i.e., "good" or "poor." In optics definition is a term denoting the ability of a lens to record fine detail.

DEFLAGRATION. The burning of explosive material at a rate slower than detonation.

DEFLECTING ELECTRODE. Electrode, deflecting.

DEFLECTION. (1) In gunnery, the horizontal angle between the bore of the gun and the direction from it to the base point. Thus the deflection is the lateral angular allowance which must be made to hit the target. It includes the corrections for wind and any other predictable or unpredictable factors. (2) In electronics, the process of changing the direction of a stream of charged particles by

subjecting them to an electric or magnetic field.

DEFLECTION FACTOR (OF A CATHODE-RAY TUBE). The reciprocal of the deflection sensitivity.

DEFLECTION OF THE VERTICAL. If the earth were a perfect sphere, suspended objects, e.g., a plumb bob, would hang in a line pointing to the center of the earth. Since the **figure of the earth** is not perfectly spherical, suspended objects, in general, hang slightly off a line to the center of the earth, the angular difference being the deflection of the vertical. This deflection varies with time and place, being greater in the neighborhood of mountains and other surface irregularities.

DEFLECTION SENSITIVITY. (1) Of an electrostatic-deflection **cathode-ray tube**, the quotient of the spot displacement by the change in deflecting potential. (2) Of a magnetic-deflection cathode-ray tube, the quotient of the spot displacement by the change in deflecting magnetic field. (3) Of a magnetic-deflection cathode-ray tube and yolk assembly, the quotient of the spot displacement by the change in deflecting-coil current. Deflection sensitivity is usually expressed in millimeters per volt applied between the deflecting electrodes, or in millimeters per gauss of the deflecting magnetic field.

DEFLECTION YOKE. An assembly of one or more coils, whose magnetic field deflects an electron beam.

DEFORMATION (STRAIN). The change in the shape or size of a body which accompanies a stressed condition. The total amount of change in any one direction is the total deformation in that direction. Unit deformation is the deformation per unit of length. Permanent deformation is known as set. If an axial load is applied to a body, the length and lateral (cross-sectional) dimensions are changed. **Poisson's ratio** is the ratio of lateral unit deformation to longitudinal unit deformation.

Deformation which is the result of a flexural stress is called bending deformation. Shearing or shear deformation is caused by shearing stress.

DEGAUSS. To neutralize locally a magnetic field, as by encircling the region to be neutralized (e.g., a ship) with a conductor.

DEGENERATION. Negative feedback. (See **feedback, negative**.)

DEGENERATIVE FEEDBACK. Feedback, inverse.

DEGN. Diethyleneglycol dinitrate.

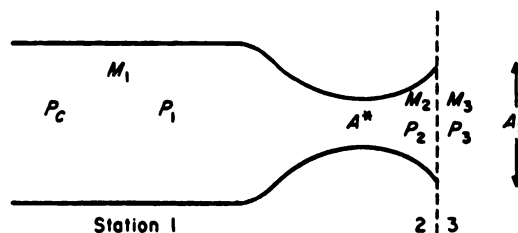
DEGREES OF FREEDOM. Freedom, degrees of.

DEI. Development Engineering Inspection.

DEIONIZATION POTENTIAL. The potential at which conduction in a **gas-discharge tube** stops, due to the cessation of ionization.

DEIONIZATION TIME. The time required for the grid of a **gas-discharge tube** to regain control after anode-current interruption. To be exact, the ionization and deionization times of a gas tube should be presented as families of curves relating such factors as condensed-mercury temperature, anode and grid currents, anode and grid voltages, and regulation of the grid current.

DE LAVAL NOZZLE. The supersonic convergent-divergent design of a nozzle credited to the Swedish engineer, Carl G. F. de Laval. By first converging and then diverging the nozzle, de Laval found that the flow accelerated in the throat, and continued to accelerate in the diverging exit, thus attaining supersonic velocities. The de Laval nozzle is the basis for all rocket motors. See figure



De Laval nozzle.

for diagram of the de Laval nozzle with notation of significant parameters. If p_2/p_1 is less than the critical pressure ratio, the **Mach number** at the throat is unity. If p_2 is less than p_3 , an oblique **shock wave** forms at the exit. If p_2 is greater than p_3 , an **expansion wave** forms there. M_2 remains constant for any given nozzle expansion ratio regardless of how much p_1 is increased. Therefore no shock wave forms inside the nozzle. Under

design conditions, the mass flow increases with the chamber pressure p_1 . Total temperature and total pressure are constant from station 1 to station 2. The speed of sound decreases between points 1 and 2. The Bernoulli equation, in the form $dp/p + VdV = 0$, is valid throughout the nozzle.

DELAY AUTOMATIC VOLUME CONTROL. Automatic volume control which is designed to act only on signals which exceed a predetermined value.

DELAY CIRCUIT. A circuit used to cause the delay for a certain period of time of the starting of a waveform. It is often necessary to admit a signal into a circuit at a particular time. For example, in a computer a serial adder may require a pulse to be delayed so that it may be used in another register as a "carry." Many methods for producing delay are available, including a triggered multivibrator whose recovery time is adjustable; a resistance-capacitance circuit which can be triggered so that its output may be used to trigger a secondary circuit, or a mercury delay line which transmits a supersonic wave from one piezoelectric transducer to another in a mercury-filled tube. Supersonic signals can also be delayed in a poly-sided quartz crystal.

DELAY DISTORTION. Distortion, delay.

DELAY LINE. An artificial transmission line employing lumped constant elements to provide a predetermined time for a waveform to traverse a line. (Delay times of 1 microsecond are readily obtainable; long times are difficult because of the large number of sections required to provide sufficient delay and still give sufficiently high cutoff frequencies.) (See also **delay circuit**.)

DELAY-LINE MEMORY. In computer terminology, a type of **circulating memory** in which a delay line is the major element in the circulation path.

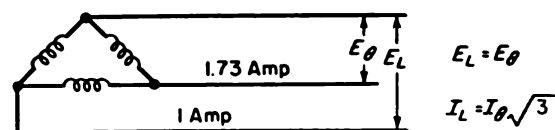
DELAY-LINE REGISTER. An acoustic or electric delay line, usually one or an integral number of words long, together with input, output, and circulation circuits.

DElayer. A substance mixed in with dry-fuel rocket propellants especially to decrease the rate of combustion.

DELLINGER EFFECT. The sudden disappearance of **skywave** signals as a result of greatly increased ionization in the **ionosphere** due to solar storms. The effect may last from ten minutes to several hours.

DELIQUESCENCE. The property of a substance whereby it absorbs water vapor from the atmosphere, eventually forming a solution.

DELTA CONNECTION. The delta connection is one of the two most frequently used ways of connecting a three-phase **alternating-current circuit**. The other is the Y connection. A three-phase machine has three coils. These coils have six ends which must, in some way, be connected to the three wires of a



Delta connection.

three-phase circuit. The delta connection, as illustrated in the accompanying figure, has the coils connected at three points corresponding to the three-phase circuit. When this is compared with the Y connection, it becomes apparent that the line voltage in delta connection equals the coil voltage, and that the line current in Y connection equals coil current. For a balanced delta load the line current is $\sqrt{3}$ times the phase (or coil) current.

DELTA WING. A triangular shaped, low aspect-ratio **airfoil** with tapered leading edge and straight trailing edge.

DELUGE SYSTEM. A water washdown system installed on missile test stands or launch stands to permit inundation in case of fire or other accident.

DEMAGNETIZATION. The process of rendering a substance non-magnetic. It may be done by heating to a red heat, violent jarring, or by placing the substance in the magnetic field of a solenoid operated on an alternating current and then gradually removing the material.

DEMODULATION (OR DETECTION). The process by which information is derived from a modulated **waveform** about the signal imparted to the waveform in **modulation**.

DEMODULATION, ENHANCED-CARRIER. An amplitude-demodulation system in which a synchronized local carrier of the proper phase is added to the **demodulator**. This has the effect of materially reducing the distortion produced in the demodulation process.

DEMODULATOR. A device to effect the process of **demodulation**.

DEMODULATOR, FREQUENCY. A device which will produce an output proportional to the variation of the instantaneous frequency of the input voltage. Ideally it will be insensitive to variations in the **amplitude** of the input wave.

DEMODULATOR, PRODUCT. A device whose output is the product of its two inputs, these being the amplitude-modulated carrier and a locally-generated voltage of **carrier frequency**. This is basically the same device as a product modulator (see **modulator, product**), and with proper filtering, can produce an output proportional to the original modulation.

DEMODULATOR, RECTIFIER. A device consisting of a **diode** or diodes through which the amplitude-modulated carrier is passed. The resulting rectified output has an average value proportional to the original **modulation**. With conditions approximating a perfect **rectifier**, the linearity of the device is quite good below 10% modulation.

DEMODULATOR, SQUARE-LAW. A device whose output voltage is proportional to the square of its input voltage. An amplitude-modulated carrier passing through such a device produces an output containing the original modulation signal as well as distortion products. The distortion products increase rapidly as the percent modulation increases.

DENITROGENATION. A method of reducing the detrimental effects of **aeroembolism**. It may be done by breathing pure oxygen or an air-oxygen mixture.

DENSITY. (1) The ratio of the mass of a homogeneous body to its volume. The average density of a non-homogeneous body is similarly defined, but the density of any portion of such a body is the ratio of the mass

of that portion to its volume. (2) In length-force-time systems of units, the term density is sometimes used to denote weight per unit volume, rather than mass per unit volume. (3) By analogy, the ratio of the number of particles or total amount of such a quantity as energy or momentum, carried by or contained in a volume to that volume. Thus one speaks of energy density, electron density, charge density, etc.

DENSITY IMPULSE. A parameter used to rate the relationship of density and performance of a **propellant**. It is defined as the product of the **specific impulse** and the **specific gravity**.

DENSITY, RADIANT. The radiant energy (see **energy, radiant**) per unit volume.

DEPARTURE. (1) The distance between the points of **take-off** and **cut-off** (of a rocket), projected upon the horizontal plane. It is more accurately called the "distance of departure." (2) In navigation, the distance due east or west made by a vehicle in its travel. It is also the point (in latitude and longitude) from which a **dead reckoning** computation begins. (3) In electronics, frequency departure is the amount of variation of a carrier frequency or center frequency from its assigned value.

DEPRESSION. (1) An extensive area of relatively low barometric pressure. (2) In astronavigation, the angular distance of an object beneath the horizontal plane through the observer. (3) In gunnery, the vertical angle to the target measured from the horizontal at the gun.

DEPRESSION ANGLE. The vertical angle measured downward from the horizontal to the **line of sight**. The angle of depression may refer to a radar beam, the muzzle of a gun, a surveying instrument, etc.

DEPTH OF FIELD. In photography, the range of distance over which satisfactory definition is obtained when a lens is in focus for a certain distance.

DERIVATIVE. The instantaneous rate of change of a function with respect to its independent variable. The usual symbol is dy/dx but y' , $f'(x)$, and other designations are also used. If the function $y = f(x)$ is

plotted in rectangular coordinates, the slope of the curve at the point $x = x_0$ is its derivative, dy/dx , at that point, and is

$$\left(\frac{dy}{dx}\right)_{x_0} = \text{Limit}_{\Delta x \rightarrow 0} \frac{f(x + \Delta x) - f(x)}{\Delta x}.$$

DERIVATIVES, STABILITY. Aerodynamic quantities expressing the variation of the forces and moments on aircraft owing to disturbance of steady motion. They form the experimental basis of the theory of stability, and from them the periods and damping factors of aircraft can be calculated. In the general case there are 18 translatory and 18 rotary derivatives.

DESCENDING NODE. Satellite elements.

DESCENT PATH. The flight path leading from an orbit in space to the surface of a celestial body including the earth.

DESIGN LOAD. Load, design.

DESIGN OBJECTIVE. A non-contractual means of specifying certain desirable performance or operating characteristics. (Frequently used when a design feature is difficult to validate: e.g., very high reliability requirements, probability of survival of blast, etc.)

DESIGN TEMPERATURE. A temperature which high speed aerodynamic surfaces must be designed to resist. It is based on the boundary layer temperature, t :

$$t = 0.84 \frac{V^2}{12,000} \text{ for laminar flow,}$$

$$t = 0.90 \frac{V^2}{12,000} \text{ for turbulent flow,}$$

where t is in °F and V is in feet per second.

DESTRUCT. The action of detonating or otherwise destroying a rocket missile or vehicle after it has been launched, but before it has completed its course, usually for reasons of safety. Thus, missiles which go off course, or become hazardous in other ways, are destroyed. The term is not usually applied to enemy missiles. (Cf. **interception**.)

DESTRUCT CIRCUIT. An electromagnetic loop (through radio or radar) by means of which an erratic missile (or a potentially dangerous missile) can be cut off or destroyed

upon command to prevent its impact in a place endangering lives or property. Destruct does not necessarily imply actual fragmentation of the entire missile, although in some instances this does result. For aerodynamically supported missiles, a major supporting lift surface may be blown off, or the aerodynamic stability may be destroyed by other means, causing the missile to break apart, or to fall in a more or less **ballistic** path for the remainder of its flight. Since destruction circuits are designed for safety, they are independent of the normal detonation circuits which explode the warhead at the target.

DESTRUCTIVE AGENT. Material contained in warheads such as explosives, corrosive chemicals, biological or radiological agents, etc., which damage or destroy the target.

DESTRUCTOR. An agent or device for intentionally destroying a missile or component for an operational reason, which is usually safety.

DETAIL SPECIFICATION. Specification, detail.

DETACHED SHOCK WAVE. A shock wave that forms ahead of a blunt body immersed in a fluid and moving at supersonic speed. The detachment is proportional to the **Mach number**, the degree of bluntness of the body (i.e., the **half-angle** of entering surface), and the medium. A wedge-shaped body produces oblique shock waves if the half-angle of the wedge is small. This shock wave remains attached to the leading edge of the wedge until a change in conditions causes it to become detached and jump forward.

DETECTION. The action or function of a detector.

DETECTOR. (1) Any device which indicates the presence of an entity of interest, such as radiant energy, without yielding directly a quantitative measurement. (2) Any device which derives from a modulated waveform information about the signal imparted to the waveform in **modulation**. (3) A device used in a **bridge circuit** or other measuring device to indicate a **null** or balance condition.

DETECTOR, BALANCED. (1) **Demodulator** for frequency-modulation systems. In one

form the output consists of the rectified difference of the two voltages produced across two resonant circuits, one circuit being tuned slightly above the **carrier frequency** and the other slightly below. (2) A detector for bridge or other null circuits, which include a balanced amplifier. (See **amplifier, balanced**.)

DETECTOR, GRID-LEAK. A type of envelope-demodulator which employs the grid of a vacuum tube as the **rectifier**. The grid circuit consists of the input, the "grid-leak" resistor, and the grid-ground terminals of the tube. A capacitor is placed across the resistor so that the reciprocal of their **time constant** is less than the highest modulating frequency, and larger than the carrier frequency. This apparatus is more sensitive than the basic diode envelope-demodulator, because the equivalent diode signal is amplified by the tube. However, because of the inherently-poor operating point required for this mode of operation, the distortion is generally quite high. (See figure under **detector, vacuum tube**.)

DETECTOR, IMPACT. A device (e.g., piezoelectric crystal) that generates a voltage upon impact with a surface. It is generally used to fire a warhead.

DETECTOR, INFRARED. Since infrared radiation is not visible to the eye, it must be detected by some physical device. These fall in a number of classes.

I. Heat Engine. A device which is warmed by the absorbed radiation and this rise in temperature results in some observable phenomenon.

- a. Thermocouple. Rise in temperature produces an emf.
- b. Bolometer and Thermister. A rise in temperature changes the resistance of a conductor through which a small electric current flows.
- c. Pneumatic Device. A rise in temperature increases the pressure (and volume) of a small volume of gas and this change is observed.

Such detectors are independent of the wavelength of the radiation in so far as the receiving surface is "black."

II. Photoconductive. Certain semiconductors become more conductive when irradiated with certain radiations. The wavelength

must be sufficiently short, that is, the photons sufficiently energetic, to lift an electron from a bound level to a conduction level. Such detectors are very wavelength-sensitive. Lead sulfide and lead telluride properly sensitized with a suitable impurity, commonly oxygen, are well known photoconductive detectors. This field is presently (1959) being rapidly developed and new and better photoconductive detectors are appearing.

III. Photoemissive. Most surfaces when irradiated with radiation of sufficiently short wavelength (sufficiently energetic photons) emit electrons which may be observed in various ways. Only few surfaces respond to the weak photons associated with short infrared radiation. The surface which emits electrons when irradiated with the longest infrared radiation which may be detected by this method (about 1.2 microns) is a special silver, oxygen, cesium surface.

IV. Photographic. Photographic emulsions when dyed with certain dyes become sensitive to infrared radiation out to about 1.2 microns.

V. A considerable number of other possible infrared detectors are being studied. Some of these offer considerable promise but have not yet shown superiority over those mentioned above.

DETECTOR, OSCILLATING (BEATNOTE DETECTOR). A **demodulator** which is either oscillating or fed from an external **oscillator**. In either case the frequency of oscillation is made to be sufficiently close to the unmodulated carrier being received so that an audible **heterodyne frequency** is produced.

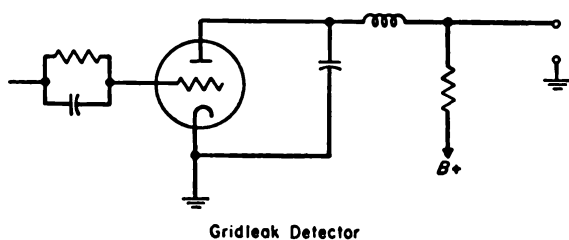
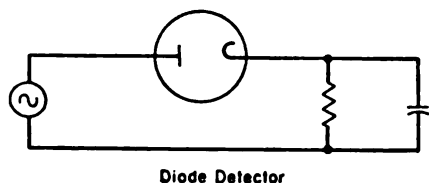
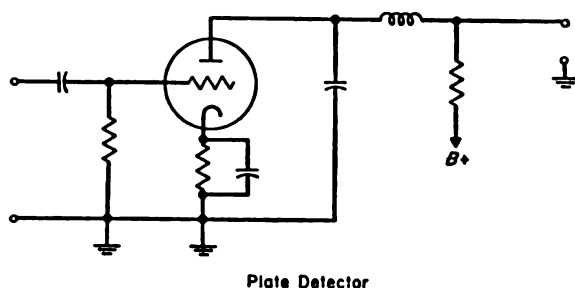
DETECTOR, PLATE. Sometimes called the "anode bend detector," it involves operation towards the point of plate-current cut-off so that non-linearity occurs, thus giving **rectification**. Sensitivity is generally fairly low, and distortion is quite high. (See figure under **detector, vacuum tube**.)

DETECTOR, PROXIMITY. A sensing device that produces an electrical signal when passing near an object, or prior to impact.

DETECTOR, REGENERATIVE. A **demodulator** whose **gain** or **conversion ratio** is increased by the addition of positive **feedback** or **regeneration** at the carrier frequency.

The **sensitivity**, small-signal **selectivity**, and distortion are increased over that found in a detector without regeneration.

DETECTOR, VACUUM TUBE. A detector employing a vacuum tube. Three types, known as "plate," "diode" and "gridleak" are commonly used. (See figure.)



Vacuum tube detectors.

DETERRENT FORCE. A force-in-being recognized by an aggressor nation to have such retaliatory power as to make the cost of aggression unacceptable.

DETONATION (EXPLOSION). An extremely rapid reaction, in which an oxidizer and a fuel combine with large evolution of heat. The release of warhead damage agents, usually by initiating a series of explosive elements arranged in a "chain." A *high-order detonation*, or "true detonation," proceeds with very high speed, generally several thousand feet per second. A *low-order detonation* is a partial, or relatively slow, explosion, generally caused by accidental or inadequate initiation. The term detonation is not to be confused with **deflagration**, which may consume the same ex-

plosive materials, but at a rate usually of the order of inches per second.

DETONATOR. A combination of a primer and another less-sensitive explosive charge. Electrical type is detonated by a current of approximately one half ampere. Typical material is tetryl in the form of a reconsolidated pellet.

DEUTERIUM. The isotope of hydrogen of mass number 2. (Denoted by d, D or H².)

DEUTERON. The nucleus of the deuterium atom.

DEVELOPMENT. The application of known techniques and principles to produce a desired result from the discoveries of research. In the development stage a device is visualized and its performance is anticipated. Development is characterized by deliberate planning, by ingenuity, and by synthesis of knowledge in many fields. The result of development is the creation of plans or models for a new device, and the demonstration by test that the prototype of the device fulfills the objective of the development.

DEVELOPMENT ENGINEERING. Creation of a design, parts of which make use of new facts discovered by research.

DEVELOPMENT ENGINEERING INSPECTION (DEI). In U.S. Air Force terminology, a formally conducted inspection of a missile or system mockup in which development and using commands review the weapon to determine desirable changes. Requests for Alterations (RFA's) are prepared by the inspection board and eventually are acted upon by the contractor.

DEVELOPMENT TYPE. In U.S. Air Force terminology, any item undergoing development, development testing, or operational suitability testing which has not yet been released as a satisfactory prototype for procurement in quantity.

DEVIATION. (1) The angle between compass north and magnetic north. (2) The angle through which a light ray is bent by refraction or diffraction. (3) A measure of departure of measurements from a value determined from them jointly. (See **average deviation**, **standard deviation**.) (4) A con-

tractual change in a specification or work statement; a temporary change or departure from a particular requirement of a contract or other document. Generally, deviations are granted prior to the existence of equipment, and waivers are granted on equipment if it does not conform to the specification. (See **waivers**.)

DEVIATION, FREQUENCY. In phase modulation and frequency modulation (see **modulation, phase**; and **modulation, frequency**) the peak difference between the instantaneous frequency of the modulated wave and the carrier frequency.

DEVIATION OF A SIGNAL. The frequency change from the center frequency governed by the amplitude of the modulating system. The modulating signal does not vary the amplitude of the carrier, but does shift the frequency and power to different sidebands.

DEVIATION, PHASE. In phase and frequency modulation, the peak difference between the instantaneous angle of the modulated wave and the angle of the carrier.

DEVIATION RATIO. In a frequency-modulation system (see **modulation, frequency**), the ratio of the maximum frequency deviation to the maximum modulating frequency of the system.

DEVIATION SENSITIVITY. The least frequency deviation (see **deviation, frequency**) that produces a specified output power.

DEW (DISTANT EARLY WARNING). A line of radar receivers for the detection of incoming targets at a considerable distance from the air defense system which must be alerted.

DEW. If air in contact with any surface is cooled at the surface to a temperature below its dew point, some of the water vapor present in the air will condense onto the cool surface as liquid water or dew. When temperatures are below freezing, **hoarfrost** forms instead.

DEW POINT. The temperature at which the actual content of water vapor in the atmosphere is sufficient to saturate the air with water vapor. If the atmosphere contains much water vapor, the dew point is higher than in the case of drier air, so that the dew point is an indication of the relative humidity

of the atmosphere. As air is cooled, condensation of moisture as water (or ice) begins at the dew point (under equilibrium conditions). The dew point is important in missile operations where low temperatures are likely to be encountered, as in space flight, or where cold fuels, such as liquid oxygen, are used. When temperatures go to low levels, any moisture in any gas carried aloft is likely to freeze. If this freezing happens inside moveable equipment, such as pneumatic valves, sticking is probable and some component may fail. Missile gas must therefore be so dry that dew points as low as -110°F result. (Liquid oxygen at useable pressures has a temperature of about -200°C . For this reason gas systems of missiles frequently use a dry inert gas, such as helium, in place of air.)

DEW-POINT HYGROMETER. Hygrometer.

DEWAR FLASK. A vessel with a double wall, in which the region between the walls has been evacuated, and in which the walls bordering this space have been silvered. With this construction the region within the inner container is very well insulated from the outside. The vessel is commonly used for storage of liquefied gases. Some types are made in large sizes designed to be transported on trailers, and to operate under pressure, which reduces their evaporative losses.

D-F. Direction finder.

D_i. Induced drag.

DIAMAGNETIC. Diamagnetic substances have a negative magnetic susceptibility and a permeability less than unity.

DIAMOND ANTENNA. Antenna, diamond.

DIAMOND BACK. A U.S. Navy study project leading to a missile successor to the **Sidewinder**.

DIAPHRAGM. (1) Usually a separating wall which transmits or passes substances or stresses selectively. Thus, a diaphragm with many small openings is used in electrolytic cells to permit passage of ions and yet to segregate reaction products. Diaphragms with a single opening, that may be adjustable in size, are used to control flow of substances or radiations. For example, in fluid-operating

systems, a diaphragm may be a thin frangible or flexible partition inserted in a fluid line or chamber to restrain the flow of a liquid or gas, or to maintain a predetermined pressure. If so designed, the diaphragm may burst at a given pressure to allow a full pressure flow of the fluid at some desirable time, e.g., ignition of a rocket motor. The flexible types of diaphragms are often used to prevent damaging pressure surges or to control fluids in other ways. (2) In acoustics, a vibrating element, as in a loudspeaker, telephone or other sound-source; also the diaphragm of the human ear.

DIBORANE. The chemical compound B_2H_6 used as a high energy fuel. It is a hydride of boron.

DIDYMIUM. A mixture of neodymium and praseodymium, e.g., didymium oxides are used in tinting glass.

DIELECTRIC. A material characterized by its relatively poor electrical conductivity, hence an insulator. For alternating fields, the dielectric nature of a substance gives rise to a **displacement current**, which leads the field variation by a 90° phase angle, whereas the conductivity of the material gives rise to an in-phase current. Since the (capacitive) displacement current increases with frequency, a substance may be a "poor" dielectric at low frequency, but "good" at high frequencies.

DIELECTRIC ANTENNA. Antenna, dielectric.

DIELECTRIC CONSTANT. (Specific inductive capacity.) A measure of that property of a medium by virtue of which it modifies the mutual interaction of electrified bodies immersed in it or separated by it. Specifically, the factor by which the **electric flux** produced by a given field is increased by the presence of the **dielectric**, or the factor by which the field produced by fixed charges is decreased. If the dielectric constant of a vacuum is taken as a reference standard and assigned the value unity, the constants for several gases and vapors (at less than 3 cycles per second) are: air, 1.000567 ($0^\circ C$); benzene, 1.0028 ($100^\circ C$); ethane, 1.0015 ($0^\circ C$); hydrogen chloride, 1.0046 ($0^\circ C$); and steam, 1.00785 (at $140^\circ C$). (See **permittivity**.) The dielectric constant customarily has the same value in all systems of units, being

a dimensionless quantity. The specific inductive capacity of empty space is expressed differently in the various systems, being unity in the esu system and 8.85×10^{-12} farads per meter in the MKSCb system. (See **units and dimensions**.)

DIELECTRIC HEATING. The heating of a **dielectric** material by molecular friction in it as a result of the application of a high-frequency, alternating electric field.

DIELECTRIC HYSTERESIS. An effect in a **dielectric** material analogous to the **hysteresis** found in magnetic materials.

DIELECTRIC LOSS. The power loss in a **dielectric** due to **dielectric heating**.

DIELECTRIC PHASE ANGLE. The angular difference in phase between the sinusoidal alternating voltage applied to a **dielectric** and the component of the resulting alternating current having the same period as the voltage.

DIELECTRIC STRENGTH. The maximum potential gradient that a material can withstand without rupture.

DIELECTRIC WEDGES. Wedge-shaped pieces of **dielectric** used to match an air-filled **waveguide** to another guide, either partially or completely filled with a dielectric.

DIELECTRIC WIRE. A **dielectric waveguide**.

DIERGOLIC (NON-HYPERGOLIC). A property of liquid propellants (oxidizer and fuel) whereby they do not react spontaneously when brought into contact, but require an auxiliary ignition system to initiate combustion.

DIETHYLENEGLYCOL DINITRATE. A substance that is a possible monopropellant for rockets. Its chemical formula is: $(CH_2CH_2ONO_2)_2O$. It has a melting point of $11.3^\circ F$, boiling point of $320^\circ F$ and a density at $68^\circ F$ of 1.39 gm/cm^3 . Theoretically it can develop an exhaust velocity of 6865 ft/sec with an I_{sp} of 213 lb-sec/lb. Chamber temperature is $4078^\circ F$ with exit temperature of $2061^\circ F$. The ratio of its specific heats is 1.236. It is considered to be a **ballistite** propellant. It is only slightly soluble in water,

but readily soluble in organic solvents such as alcohol, acetone and ether. It is sometimes referred to as DEGN.

DIMETHYLHYDRAZINE. Unsymmetrical dimethylhydrazine (UDMH) ($\text{H}_2\text{NN}(\text{CH}_3)_2$), a missile propellant related to hydrazine; both are colorless liquids which tend to turn yellow if exposed to air. It is hygroscopic and fumes heavily. It has a density of 49.18 lbs/cubic foot (at 77°F) or 6.58 lbs/gallon at the same temperature. Its boiling point (at 760 mm of mercury) is 63.1°C, freezing point -57.15°C. It is totally miscible in water, alcohol, ether, and benzene at room temperatures. Explosive limits for DMH vapor in air are 3-45% by volume. Explosion is most violent at 4%. DMH is sensitive to air oxidization and losses. Handling crews require goggles, rubber gloves and protective clothing. A canister gas mask is to be used where vapors are present. Containers should be stored in cool places out of direct rays of sun. When opening containers, caution must be observed in releasing any pressure developed. Containers should be grounded while unloading the contents. Because of the low flash point, DMH should not come into contact with open flames or oxidizing agents. If spillage occurs, it should be flushed with large quantities of water. Because of its hygroscopic characteristics and sensitivity to loss by oxidization, exposure of dimethylhydrazine to air is to be kept to a minimum. Nitrogen padding is recommended.

DIFFERENCE AMPLIFIER. An amplifier having two inputs, and whose output is a function of their difference.

DIFFERENCE DETECTOR. A circuit whose output is a representation of the differences of the peak amplitudes or areas of the input waveforms. The input waveforms need not occur simultaneously.

DIFFERENTIAL. If the variable y depends on the single independent variable x , so that $y = f(x)$, their differentials are designated by dy and dx . If $dx \neq 0$, the ratio of the differentials is the derivative of y with respect to x

$$\frac{dy}{dx} = \frac{f'(x)dx}{dx} = f'(x).$$

DIFFERENTIAL ANALYZER. An analog computer used to solve differential equations.

DIFFERENTIAL EQUATION. In mathematics, an equation involving **derivatives** or **differentials**. If the equation contains total differentials, total derivatives, or both, it is called an *ordinary differential equation*, for example:

$$\frac{dy}{dx} = x^2 + 3$$

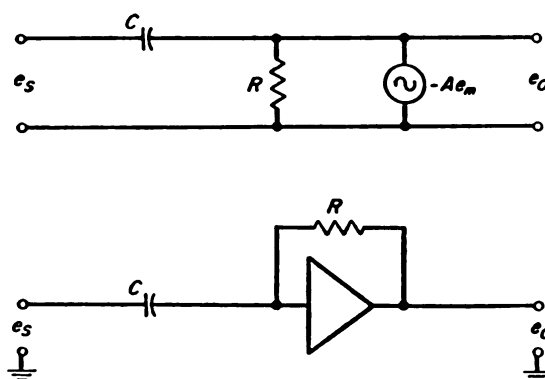
If partial derivatives occur, it is called a *partial differential equation*, for example:

$$\frac{\partial^2 y}{\partial x^2} = x$$

DIFFERENTIAL EQUATION, LINEAR. A differential equation of the first degree. When written with integral exponents, it is an equation in which the unknown function and its derivatives occur only to the first power.

DIFFERENTIAL PHASE SECTION. A waveguide filter which introduces a phase difference between individual components being transmitted.

DIFFERENTIATING CIRCUIT. A grouping of components that possesses the ability to produce an output voltage proportional to the rate of change of the input signal. (See figure.)



Differentiating circuits.

DIFFERENTIATING NETWORK. Network, differentiating.

DIFFRACTION. (1) For the use of this term in acoustics, see **wave, diffracted**. (2) In optics, the interference pattern resulting from the rays through different parts of an

opening, or from different points around an opaque object as they unite at each point.

Fresnel Diffraction. The intensity at any point is the resultant of disturbances coming directly to that point from all parts of the exposed wave front. In general, the wave front is spherical or circular, resulting from a source at finite distance, and the point of observation is also at finite distance.

Fraunhofer Diffraction. A lens is placed beyond the aperture or obstacle, and the diffraction pattern is examined in the plane where a sharp image of the source would be formed in the absence of the aperture or obstacle. In general, Fraunhofer diffraction is a phenomenon observed at effectively infinite distance from the aperture or the obstacle, and the source is also effectively at infinite distance.

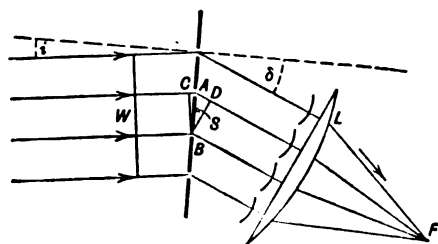
For a single slit of width a and light of wavelength λ , falling on the slit at normal incidence, the intensity of light at an angle θ from the normal to the slit is given by

$$I = R_0^2 \frac{\sin^2 \left(\frac{\pi a \sin \theta}{\lambda} \right)}{\left(\frac{\pi a \sin \theta}{\lambda} \right)^2}$$

Other diffraction patterns have been computed, but are more complicated. (See Robertson, *Introduction to Optics*, 4th ed., Chapters X and XI.)

DIFFRACTION GRATING. A series of very fine, closely spaced parallel slits, or of very narrow, parallel reflecting surfaces, which, when light is incident upon it at a definite angle, produces a succession of spectra. The complete optical theory is somewhat complicated, but the action of a plane transmission grating may be explained approximately as follows.

A plane, monochromatic light wave W , incident at angle i (see figure), reaches the slits



Diffraction by a plane grating.

at different times. A lens L receives the waves emerging from any two adjacent slits, A and B (among many others), after they have traveled paths differing by $CA + AD$; that is, by $S \sin i + S \sin \delta$, in which $S = AB$. If the lens is so placed that this path difference is a whole number of wavelengths, $n\lambda$, the successive wave-trains will reach it in the same phase, so that when they are brought to the focus F , they will be in synchronism and will produce a bright image of the distant source. Therefore any angle δ for which this result is possible is subject to the condition

$$S \sin i + S \sin \delta = n\lambda,$$

or

$$\sin \delta = \frac{n\lambda}{S} - \sin i.$$

Bright images will be produced for those angles δ which correspond to $n = 1, 2, 3, 4, \dots$; the numbers denote the "orders" of the images. It is easily shown that for any order the total deviation ($i + \delta$) is least when $\delta = i$ and therefore when

$$\sin \delta = \frac{n\lambda}{2S}.$$

If the incident light is composed of various wavelengths, the corresponding images of any order will appear at different points, since δ varies with λ ; and the result is a spectrum. In short, the grating acts as a dispersion piece, and as such is of great value in spectroscopes and spectrographs.

DIFFUSER. (1) A duct of varying cross section designed to convert a high-speed gas flow into low-speed flow at an increased pressure. The following are the common types of supersonic diffusers: (See Figures 1 and 2) (a) The normal shock diffuser, so called from the normal **shock wave** that occurs at its throat when operating properly. This type is also called a "Kantrowitz-Donaldson" or "simple cowl inlet" diffuser. It is designed for use at Mach 1.4 or below. According to theory it first contracts the flow into a throat, and then expands it into the combustion chamber. The normal shock wave occurs near the throat at decreased stream velocity, thereby decreasing the shock wave strength, and the pressure loss which would occur if the normal shock had occurred at the lip of the diffuser. It is also called a "reverse de Laval nozzle" because of its configuration. The

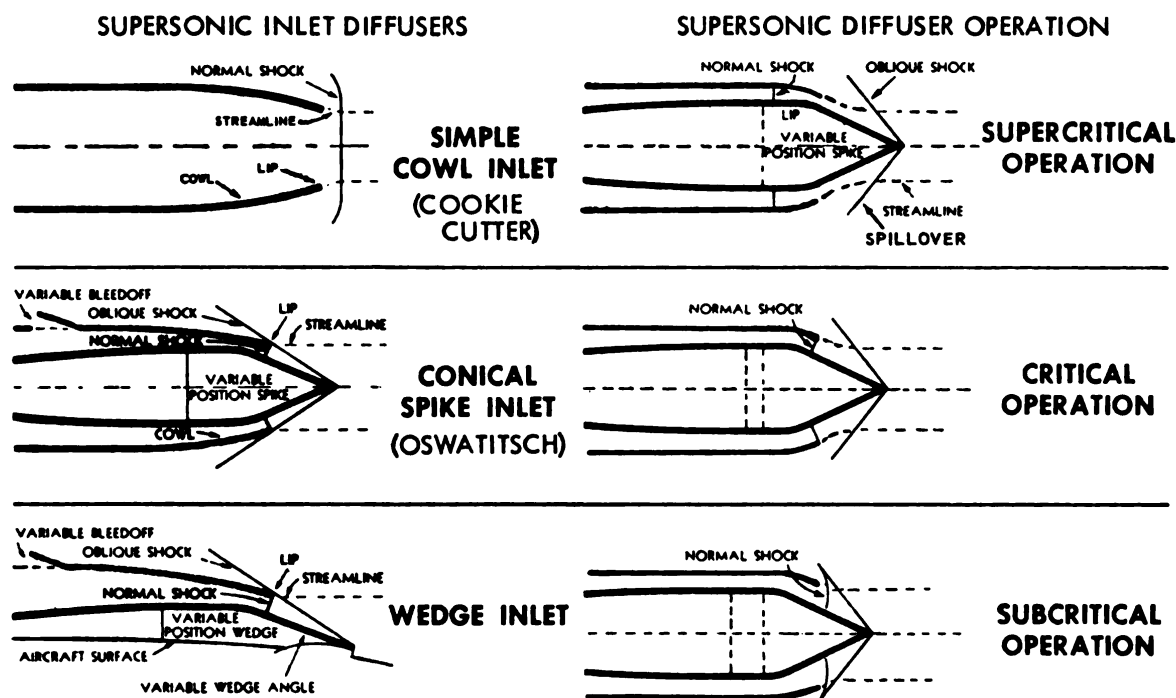


Fig. 1

total pressure recovery is not great since this type of diffuser is not efficient. Normal shock waves can exist anywhere within the nozzle or a **detached shock wave** can exist in front of the diffuser, but only one normal shock wave can exist at a time. If the A_t/A_1 ratio is decreased the shock wave may jump out of the diffuser ("regurgitate"), and the mass flow through the inlet then decreases seriously, since the bulk of the flow would be spilled over the lip. Flow through this diffuser is adiabatic, but the flow through the normal shock itself is not isentropic. (b) The oblique shock diffuser or conical spike inlet diffuser is a type employing an inner body projecting forward of the intake lip, so shaped as to raise pressures gradually through a series of conical shocks. The pressure recovery of

this type is higher at large Mach numbers than could be obtained from the normal shock diffuser. It is called variously a spike diffuser, Oswatitsch or Ferri diffuser according to its designed position for the oblique shock wave. A normal shock wave can be present in the throat of the diffuser even if there is an oblique wave at the spike or even if the spike wave is reflected within the diffuser channel. As the speed of travel of the diffuser increases, the **Mach angle** will increase for the normal shock wave and spillover will occur. It is not mandatory that there be a normal shock wave inside the throat, and if the spike angle is proper, or the speed a certain value, it will not exist. (2) A device which broadens a beam of radiant energy by diffusion.

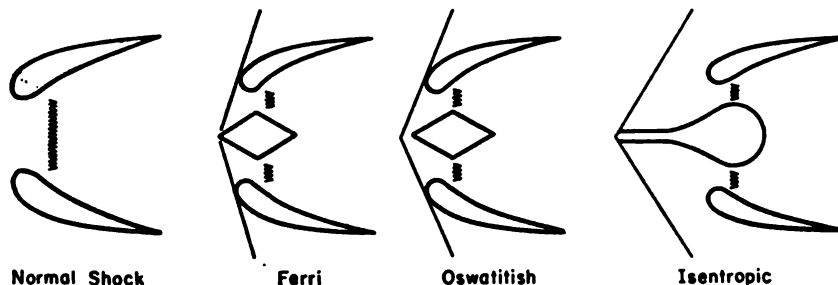


Fig. 2. Supersonic diffuser in normal shock position.

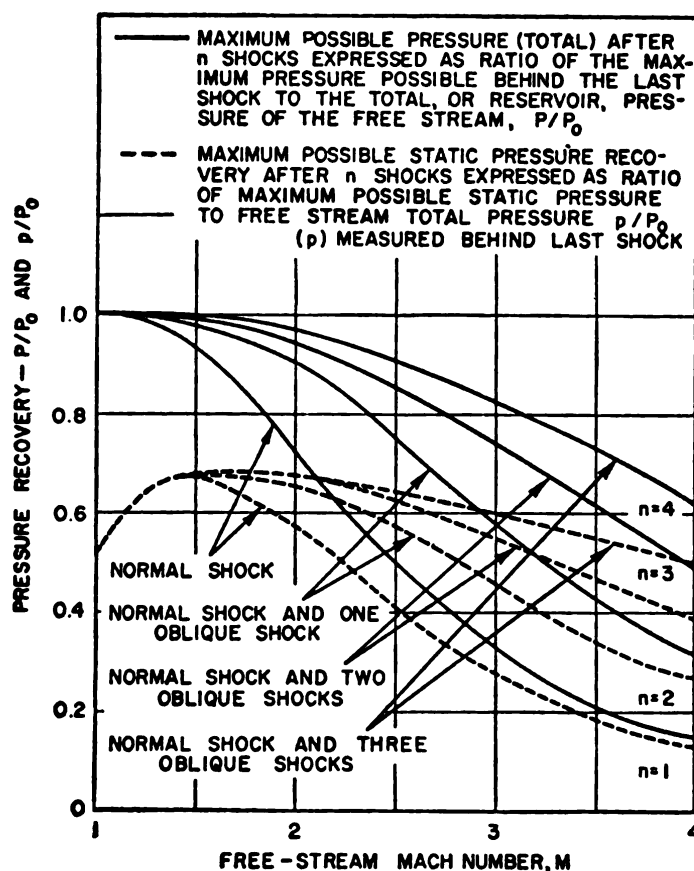


Fig. 1. Ratios P/P_0 and p/p_0 as a function of the free-stream Mach number for conical shock supersonic diffusers with different numbers of shocks.

DIFFUSER, AREA RATIO OF. The ratio of the outlet cross-sectional area of a ramjet diffuser to the inlet cross-sectional area.

DIFFUSER BUZZ. In ramjet engines, an oscillatory motion with alternate swallowing and expelling of the normal shock system resulting in pressure variations throughout the diffuser. Buzz can only occur when the normal shock is expelled outside the cowl intake lip.

DIFFUSER EFFICIENCY. (1) The ratio of the actual pressure increase realized by a diffuser to the theoretical pressure increase realized in an isentropic process. (2) The ratio of the stagnation pressures after and before the diffuser. (3) The ratio of actual change in enthalpy to the ideal change in enthalpy for passage from ambient to diffuser pressure. (See Fig. 1 and Fig. 2.)

Diffuser efficiency is normally determined by experiments, and is primarily a function of the entrance Mach number. For low Mach numbers, a diffuser efficiency of 0.85

represents good design. At higher Mach numbers, due to the presence of shock waves in the transition from supersonic flow to subsonic flow, the efficiency is lower.

DIFFUSER, KANTROWITZ-DONALDSON. A supersonic diffuser (see **diffuser, supersonic**)

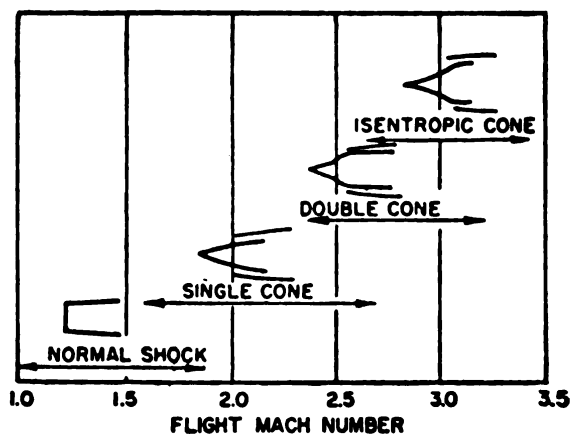


Fig. 2. Best design operating ranges for different supersonic diffusers for ramjet engines.

which first contracts to a throat and then expands. Under proper operating conditions, a normal shock occurs near the throat at decreased gas stream velocity, thereby decreasing the shock-wave strength and the pressure losses which would occur if the normal shock had occurred at the lip of the diffuser.

DIFFUSER, OSWATITSCH (FERRI OR SPIKE). A supersonic diffuser (see **diffuser**, **supersonic**) for a ramjet, with an inner body projecting forward of the diffuser lip designed to permit pressures to be raised gradually through a series of conical shocks. The pressure recovery possible with this type of diffuser operating at high Mach numbers is considerably greater than could be obtained by a diffuser designed for single normal shock.

DIFFUSER, PERFORATED INLET. An intake designed to reduce spillover of the approaching supersonic air by causing some of the air entering the **diffuser** to flow through the perforations due to the differential pressure. The effect is to move the shock wave closer to the diffuser intake.

DIFFUSER SPILLOVER. That part of the approaching free air stream that does not enter the **diffuser** directly, but is spilled over the lips.

DIFFUSER, SUBSONIC. The forward section of an air-breathing engine which reduces the Mach number of the supersonic stream to the low value required at the entrance to the combustion chamber.

DIFFUSER, SUPERSONIC. The forward section of an air-breathing engine which is designed to reduce the supersonic airstream to practically a sonic stream.

DIFFUSION IN SOLIDS. A phenomenon which occurs rather slowly, but can be observed. Three basic processes may be responsible: (a) Direct exchange of atoms on neighboring sites. (b) Migration of interstitial atoms. (c) Diffusion of vacancies. The first process requires very large energy. The energy to make an interstitial migration is rather large, but many atoms migrate easily. Vacancies are fairly readily formed, and diffuse fairly easily. From the Kirkendall effect it appears that (b) and (c) are the usual processes. The diffusion coefficient is related to the ionic mobility by the Einstein relation.

DIFFUSION RESPIRATION. The maintenance of oxygen passage through the respiratory system to the blood in the absence of respiratory movements.

DIGIT. One of a definite set of characters which are used as coefficients of powers of the **radix** in the positional notation of numbers.

DIGIT(S), SIGNIFICANT. (1) In computer work, the digits of a number can be ordered according to their significance; the significance of a digit is greater when it occupies a column corresponding to a higher power of the **radix**. The significant digits of a number are a set of digits from consecutive columns, beginning with the most significant digit different from zero, and ending with the least significant digit whose value is known or assumed to be relevant. (2) In the expression of the magnitude of a physical quantity, the significant digits are those which are believed to be closer to the true value than any other digit would be. Thus the quantity 1830 ± 2 has four significant digits, while the number 1830 ± 20 has only three and is preferably written as 1.83×10^3 .

DIGITAL COMPUTER. A computer in which information, numerical or otherwise, is represented by means of combinations of characters in such a way that the number of distinguishable combinations is much greater than the number of distinguishable characters. Thus, a digital computer is one which makes explicit use of a language. A digital computer operates upon numbers to perform even the most complex calculations by repetitions of the operations of addition and subtraction in light of logical decisions, often with the aid of a memory unit.

DIGITAR. A device used to convert analog data into digital data (usually binary numbers), by means of mechanical manipulations. For example, radar **selsyn** data in spherical form must be fed to digital computers in binary coded digits, and this conversion is effected by a digitar.

DIGIVERTER. A computer accessory which converts digitalized data to analog form for plotting.

DIHEDRAL. In aerodynamics, an airfoil design in which the tips are higher than the

roots. When viewed from the nose, the wings (or other surfaces) appear to incline upward from the root to the tip. The effect is to increase the lateral stability of the airframe.

DIHEDRAL ANGLE. (1) The angle between two planes. (2) The angle which any airfoil surface makes with the horizontal when viewed from a point in line with the longitudinal axis of the airframe to which it is attached.

DIMAZINE. Trade name for unsymmetrical dimethylhydrazine.

DING DONG. A U.S. Air Force air-to-air missile with an atomic warhead. It was developed by the Douglas Aircraft Company. An early version used guidance by Hughes Aircraft and a North American Rocketdyne liquid rocket. Later versions were reported to use a solid propellant rocket. This missile has also been called: Bird Dog, Genie, High Card, MB-1, Tingaling.

DINITROTOLUENE. A high explosive sometimes used in solid propellant rocket fuels. Its chemical composition is $\text{CH}_3\text{C}_6\text{H}_3(\text{NO}_2)_2$. It is commonly called DNT.

DINOL. The commercial name for diazo-dinitrophenol.

DIODE. A two-electrode device, having an anode and a cathode, which has marked unidirection characteristics. (See **tube, electron; diode, crystal; diode, junction; diode, semiconductor.**)

DIODE, CRYSTAL. A diode consisting of a semiconducting material, such as a germanium or silicon, as one electrode, and a fine wire "whisker" resting on the semiconductor as the other electrode. Because of its low capacitance, the device finds considerable application as a rectifier or detector of microwave frequencies.

DIODE, JUNCTION. A semiconductor with good rectifying characteristics; generally less noisy than point contact types.

DIODE, SEMICONDUCTOR. A two-electrode semiconductor device having an asymmetrical voltage-current characteristic.

DIOPTER. In optics, a unit of measurement of power of lenses. The power in diopters

equals the reciprocal of the focal length in meters; thus a lens whose focal length is .2 meters has a power of 5 diopters.

DIP (MAGNETIC INCLINATION). The angle, in the plane of the magnetic meridian, that a compass magnet is inclined to the horizontal.

DIPHENYLAMINE. A stabilizing constituent of some solid propellants, commonly used in proportions of 0.8-1%. Its chemical composition is $(\text{C}_6\text{H}_5)_2\text{NH}$. Its specific gravity is 1.16 at 20°C. It has a melting point, 53°C to boiling point of 302°C.

DIPOLE. (1) A combination of two electrically or magnetically charged particles of opposite sign which are separated by a very small distance. (2) Any system of charges, such as a circulating current, which has the properties that: (a) no forces act on it in a uniform field; (b) a torque proportional to $\sin \theta$, where θ is the angle between the dipole axis and a uniform field, does act on it; (c) it produces a potential which is proportional to the inverse square of the distance from it.

DIPOLE ANTENNA. Antenna, dipole.

DIPOLE, ELECTRIC. Electric dipole.

DIPOLE, FOLDED. Antenna, folded-dipole.

DIRECT COUPLING. The connection of two circuits directly or through a common component.

DIRECT CURRENT. Current, direct.

DIRECT-CURRENT AMPLIFIER. Amplifier, direct-current.

DIRECT WAVE. Wave, direct.

DIRECTION. The angular measure, usually from true north, to a point of interest. At any point along a trajectory it is the inclination of the trajectory to the meridian of the point, measured clockwise from 000 degrees at true north through 360 degrees. In designating direction on a proving ground, the terms *off-range*, *downrange* and *uprange* are used. Their sense is determined by facing in the direction that the missile flies. Off-range is to the left or right, downrange is in the direction

of flight, and uprange is toward the launching point from the target point.

DIRECTION COSINE. Let a set of rectangular coordinate axes in space be chosen and let L be any line in space. Through the origin of the coordinate system draw another line L' , parallel to the given line L . Let α , β , γ be the angles which L' makes with the X -, Y -, Z -axes, respectively. These angles are the direction angles of the given line and their cosines $\lambda = \cos \alpha$, $\mu = \cos \beta$, $\nu = \cos \gamma$ are the direction cosines of the line. When two angles are given, the third can be found, except for sign, by the Pythagorean theorem

$$\lambda^2 + \mu^2 + \nu^2 = 1.$$

DIRECTION FINDER, ADCOCK. A radio direction finder (see **direction finder, radio**) which utilizes special antenna construction to obtain more accurate results by the elimination of polarization errors.

DIRECTION FINDER, CATHODE-RAY H.F. A radio direction finder (see **direction finder, radio**) using a cathode-ray presentation to show the bearing of a station whose transmission is being monitored. It is an extremely fast method of bearing determination.

DIRECTION FINDER, RADIO. A sensitive radio receiver used in conjunction with a direction antenna (see **antenna, directional**) which will permit the determination of the direction from which a transmission is being sent.

DIRECTION OF PROPAGATION. At any point in a homogeneous, isotropic medium, the direction of time-average energy-flow. In a uniform waveguide, the direction of propagation is often taken along the axis. In the case of a uniform lossless waveguide, the direction of propagation at every point is parallel to the axis, and in the direction of time-average energy-flow.

DIRECTIONAL ANTENNA. Antenna, **directional**.

DIRECTIONAL BALANCE. The balance of an aircraft, rocket, etc., with respect to its vertical axis.

DIRECTIONAL CONTROL. Control which enables the guidance of an aircraft, rocket, etc., in a desired direction.

DIRECTIONAL COUPLER. A device used to transfer a small amount of radio-frequency power from one waveguide to another as a means for measurement of transmitter frequency, spectrum of the transmitted pulse and receiver sensitivity. (Used in conjunction with a slotted guide or line.)

DIRECTIONAL GAIN. Directivity index.

DIRECTIONAL GYRO. (1) A flight instrument incorporating a gyroscope that holds its position in azimuth and so indicates angular deviation from heading. (2) A gyroscope that provides directional stability in an automatic pilot or similar mechanism.

DIRECTIONAL STABILITY. Stability, **directional**.

DIRECTIVE GAIN. In a given direction, 4π times the ratio of the radiation intensity in that direction to the total power radiated by the antenna.

DIRECTIVE PATTERN. A radiation pattern.

DIRECTIVITY. For an antenna, the value of the directive gain in the direction of its maximum value.

DIRECTIVITY FACTOR. (1) Of a transducer used for sound emission, the ratio of the intensity of the radiated sound at a remote point in a free field on the principal axis to the average intensity of the sound transmitted through a sphere passing through the remote point and concentric with the transducer. The frequency should be stated. The point of observation must be sufficiently remote from the transducer for spherical divergence to exist. (2) The directivity factor of a transducer used for sound reception is the ratio of the square of the electromotive force produced in response to sound waves arriving in a direction parallel to the principal axis to the mean square of the electromotive force that would be produced if sound waves having the same frequency and mean-square pressure were arriving at the transducer simultaneously from all directions with random phase. The frequency should be stated. For an electroacoustic transducer obeying the reciprocity theorem, the directivity factor for sound reception is the same as for sound emission. These definitions may

be extended to cover the case of finite frequency bands whose spectra must be specified. Directivity factor in acoustics is equivalent to **directivity** as applied to antennas.

DIRECTIVITY INDEX (DIRECTIONAL GAIN). Of a **transducer**, an expression of the **directivity factor** in decibels, viz., 10 times the logarithm to the base 10 of the directivity factor.

DIRECTIVITY PATTERN (DIRECTIONAL RESPONSE PATTERN) (BEAM PATTERN). Of a **transducer** used for sound emission or reception, a description, often presented graphically, of the **response** of the transducer as a function of the direction of the transmitted or incident sound waves in a specified plane and at a specified frequency. A complete description of the directivity pattern of a transducer would require three-dimensional presentation.

DIRECTOR. In an **antenna array**, a parasitic element placed in front of a driven element. Its purpose is to sharpen the **directivity** of the array, and to increase its **gain**.

DIRIGIBLE. (1) Steerable. (2) A steerable lighter-than-air craft.

DISARMING (UNARMING). The act of rendering the armanent system of a missile incapable of operation by interrupting the explosive train.

DISCHARGE. (1) The removal of charge from a **capacitor**. (2) The passage of electric current through a gas. (3) The volume of fluid passing a particular cross-section of a stream in unit time. (4) The process in which a storage battery delivers electrical energy.

DISCHARGE CORRECTION FACTOR. In rocket propulsion, the ratio of the actual mass flow to the theoretical mass flow. Symbolically it is

$$\left[\frac{dm}{dt} \right]_{\text{Actual}} \text{ divided by } \left[\frac{dm}{dt} \right]_{\text{Theoretical}} .$$

Its values range from 0.98 to 1.15.

DISCHARGE TUBE. (1) A tube biased to **cut-off**, and therefore non-conducting except when triggered by a positive **pulse**. A condenser, connected in the plate circuit of

the tube, charges when the tube is non-conducting and discharges when the tube is triggered and forced into conduction. The tube may be either vacuum or gaseous. (2) Any tube containing a gas or vapor at low pressure and capable of showing a gaseous discharge.

DISCOVERER. **Project Discoverer.**

DISCRETENESS. (1) The distribution of allowed values of a physical quantity over a given interval. The distribution is discrete if only a denumerable set of values is permitted. This is the case, for example, with the allowed frequencies of vibration of a finite stretched string. (2) Quality of a target which distinguishes it from its background.

DISCRIMINATOR. (1) A device wherein amplitude variations are derived in response to frequency or phase variations. (2) A circuit used with counters, having the property that only pulses falling between two limits of amplitude (one of which may be 0 or ∞) are recorded. (3) A special type of detector circuit used after amplification in the IF stage to establish whether the IF deviates from the correct value.

DISCRIMINATOR CIRCUIT. A frequency or phase **modulation detector** which causes the magnitude and polarity of its output to be determined by the variation of the input phase or frequency.

DISH (OR DISH, RADAR). Colloquialism for parabolic antenna. (See **antenna, parabolic**.)

DISPERSION. (1) The scatter of impact points of shells or missiles about a target point. (See also **deviation**.) Causes of dispersion are weight and surface variations between projectiles, and variations in the aerodynamic forces which are neglected in obtaining the ideal **trajectory**. These include lift, pitching force, increased drag with yaw, etc. Drag simply causes the actual trajectory to be below the ideal trajectory. The lift and pitching forces can cause dispersion in any direction. Dispersion can be reduced by imparting a slow spin to the projectile. A single rotation per 2000 feet of travel can make a significant decrease in dispersion for any range as great as 2000 feet. (2) The process of separation of radiations, e.g., complex sound

waves, etc. into components, in accordance with some characteristic such as frequency, wavelength or energy. For example, a prism or grating disperses white light by sending its component light of different wavelengths in different directions. (3) Quantitatively, a general measure of such dispersion is the derivative of the deviation with respect to that variable (wavelength, frequency, etc.). (4) Dispersion of a medium is also expressed as the rate of change of index of refraction with wavelength (or frequency, etc.).

DISPERSION LADDER. A statistical device used in ballistics to determine the probability that any given round or any given number of rounds will fall near a certain area. The dispersion ladder gives percentages of projectiles (or any other random events) which will fall in the zones indicated. The total length of the dispersion ladder is determined by experience. There are two dispersion ladders used in ballistics, one in range, and another, which is much narrower and which is called the lateral dispersion ladder from its relative position. (See figure.)

2%	7%	16%	25%	25%	16%	7%	2%
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Dispersion ladder.

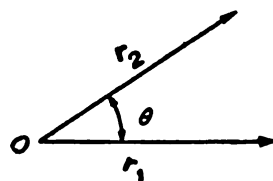
DISPLACEMENT. (1) The vector representing the change in position of a particle. In one-dimensional motion such as a **simple harmonic oscillator**, the displacement can be considered as a scalar. (2) In a piston and cylinder mechanism, the volume swept out by the piston face. It is assumed that the face of the piston is coplanar. Given the bore and stroke as D and L , the number of cylinders n , the displacement is:

$$\frac{\pi D^2 L n}{4}$$

(3) The portion of a ship which is immersed displaces a certain weight of water. According to Archimedes' principle, a body immersed in water is buoyed up by a force equal to the weight of water displaced by the body. Hence the displacement of a ship in tons of water is equal to the weight of the ship and of its contents. Various legal and conventional

definitions of the displacement of a ship are related, but not equal, to the buoyancy.

DISPLACEMENT, ANGULAR. If the vector r_1 is displaced to the new position r_2 , the



Angular displacement.

angular displacement θ is defined as the angle between the two vectors. It is itself a vector only for infinitesimal displacements.

DISPLACEMENT GYROSCOPE. Gyroscopic displacement.

DISSOCIATION. A decomposition reaction that is reversible, that is, the products can recombine, under suitable alteration of conditions, to reform the original substance. Dissociation processes are of interest in astronautics because of the relatively great energy available upon recombination of dissociated atoms and radicals which, if methods for their storage or production on missiles or space ships were devised, or if such particles from the upper atmosphere could be utilized, would be effective propellants. Another dissociation process of interest is the atmospheric dissociation produced by high speed missiles or rockets. At Mach numbers between 10 and 14, this effect becomes considerable. Dissociation is also a significant factor in the combustion processes of a rocket.

DISTANCE MEASURING EQUIPMENT (DME). A generalized term pertaining to **guidance, range instrumentation** or safety systems designed to indicate the radial distance between two locations. An example of such equipment is a radio aid to navigation that determines the distance from a transponder beacon by measuring the total time of transmission to and from the beacon, or by employing a triangulation system which uses **continuous-wave** signals.

DISTORTION. (1) One of the five geometrical aberrations of optics with spherical surfaces. This aberration is due to the variation in magnification with the distance from

the axis. (2) In acoustics, a change in wave form. Noise and certain desired changes in wave form, such as those resulting from **modulation** or **detection**, are not usually classed as distortion. (3) In electromagnetics, an undesired change in wave form.

DISTORTION, DELAY. Distortion due to variation of the **propagation time** of the system with frequency.

DISTORTION, HARMONIC. Nonlinear distortion characterized by the appearance in the output of harmonics other than the fundamental component when the input wave is sinusoidal. Harmonic distortion is sometimes called amplitude distortion.

DISTRIBUTED CAPACITANCE. Capacitance, distributed.

DISTRIBUTED CONSTANT (FOR A WAVEGUIDE). A circuit parameter that exists along the length of a **waveguide**. For a transverse **electromagnetic wave** on a two-conductor **transmission line**, the distributed constants are series resistance, series inductance, shunt conductance and shunt capacitance per unit length of line.

DISTURBED ORBIT. Orbit, disturbed.

DITCHING DEVICE. A device designed to effect an automatic landing or deliberate crash landing of a pilotless air vehicle, should remote control be lost.

DITHER. A force of controlled amplitude and frequency applied to a servo-motored transfer valve, so that the valve is constantly in small amplitude motion and cannot stick at its null position. Also termed **Buzz**.

DIVE. With respect to missiles, the descending maneuver of an aerodynamically-supported surface-to-surface missile in approaching the target. There are three basic types of dives: (1) The gravity-biased dive in which the missile dives straight into the target

from some predetermined distance; (2) The vertical dive in which the missile descends to the target from a point directly over it, and (3) The ballistic dive in which a **zero-lift trajectory** is followed. (See figure.)

DIVERSITY RECEPTION. **Fading** has been found to vary from place to place at a given time. Thus if a radio signal is received simultaneously at points separated by a few wavelengths' distance it is found that the outputs of the receivers do not all fade together. Diversity reception is a method of utilizing this effect to minimize the fading. Basically such a system consists of 2 or more (3 is quite common) antennae separated by several wavelengths (at least 10 times the wavelength of the received wave is desirable and 3 antennae placed at the vertices of an equilateral triangle give the best positioning) feeding separate radio-frequency receiver channels. The outputs of these channels are then combined to give a single output. By means of automatic gain control circuits the antenna receiving a non-faded signal supplies most of the output and as the signals at the different antennae fade out and back in, the control system acts to maintain a constant output level. While such a system, because of its complexity, is not suitable for home reception, it is widely used for reception of foreign broadcasts for rebroadcasting in this country. It is also used for transoceanic telephone reception.

DIVIDING NETWORK. Network, cross-over.

DME. Distance measuring equipment.

DN. Department of the Navy.

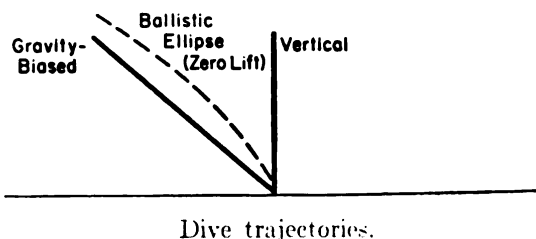
D_o. Profile drag.

DOD. Department of Defense.

DOFL. Diamond Ordnance Fuze Laboratory, a U.S. Army Ordnance agency located in Washington, D.C.

DOMINANT WAVE. Wave, dominant.

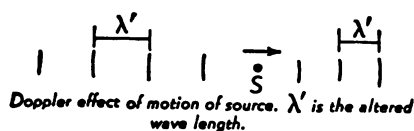
DOMINANT WAVELENGTH. The **wavelength** of light of a single frequency, which matches a color when combined in suitable proportions with a reference standard light. Light of a single frequency is approximated in



practice by the use of a range of wavelengths within which there is no noticeable difference of color. Although this practice is ambiguous in principle, the dominant wavelength is usually taken as the average wavelength of the band used in the mixture with the reference standard matching the sample. Many different qualities of light are used as reference standards under various circumstances. Usually the quality of the prevailing illumination is acceptable as the reference standard in the determination of the dominant wavelength of the colors of objects.

DOPPLER DRIFT. The drift of a missile as determined through use of **Doppler radar**.

DOPPLER EFFECTS. The effects upon the apparent frequency of a wave train produced (1) by motion of the source toward or away



from the stationary observer, and (2) by motion of the observer toward or from the stationary source; the motion in each case being with reference to the (supposedly stationary) medium.

The Doppler effects are of great importance in the case of light (for which it is quite impossible to distinguish between them because only the relative velocity of observer and source is of relativistic importance).

The slight abnormality (Doppler shift) in the positions of the spectrum lines from a star, for example, affords a fairly accurate value of the relative speed with which the star and the earth are approaching or receding from each other (the radial velocity). Many double stars (spectroscopic binaries) are recognized as such only by the doubling of their spectrum lines due to the components moving in opposite directions. The spectrum lines of gases are often broadened because of the various speeds of the molecules.

For sound waves, the observed frequency f_0 , in cycles/sec, is given by

$$f_0 = \frac{v + w - v_0}{v + w - v_s} f_s$$

where v is the velocity of sound in the medium, v_0 is the velocity of the observer, v_s

is the velocity of source, w is the velocity of wind in the direction of sound propagation, and f_s is the frequency of source.

For optical waves

$$f_0 = f_s \sqrt{\frac{c + v_r}{c - v_r}}$$

where v_r is the velocity of the source relative to the observer and c is the speed of light.

DOPPLER RADAR. Radar, either continuous-wave or pulsed, which utilizes the Doppler frequency shift of a reflected echo due to relative motion of target and radar. (For comparable maximum range performance, the peak power of a pulsed radar is likely to be of the order of hundreds of kilowatts and that of a continuous-wave Doppler radar, of tens of watts. The average powers of these two radar systems, however, are equal if they are designed to have the same maximum range capability. A Doppler system, unless gated, is capable of unambiguous tracking under the special condition that only one moving target exist within the antenna beam. This condition is no different than that encountered in a pulsed radar, in that some special feature of the target, usually its range, allows it to be selected from all others for tracking. In a Doppler system only two means of selection are available, namely, Doppler signal frequency and Doppler signal amplitude. The basis of selection is usually Doppler frequency and the mechanism is commonly a highly selective tunable filter such as is contained in commercial wave analyzers. Narrowing the filter bandwidth gives a greater amount of definition just as reducing the range gate duration in a pulse radar improves definition.) (See figure under **CW Radar**.) (See also **DOVAP**.)

DOPPLER SHIFT. (1) The magnitude of the change in the observed frequency of a wave due to the **Doppler effects**. (2) In radio technology, a Doppler phenomenon analogous to that occurring in sound propagation. The amount of the shift is doubled because of the two-way transmission (to the target and return). The comparison between the transmitted and received frequencies results in a difference, or beat frequency, sometimes termed the **Doppler frequency** f_D .

DORAN. A Doppler ranging system (elliptical) using phase comparison to establish mis-

sile range which is similar to the **DOVAP** Doppler System; **DORAN** has certain advantages. In the **DORAN** system, the carrier wave has three different modulations impressed, namely 1 mc/s, 0.1 mc/s, and 0.01 mc/s, respectively. By a phase comparison method, it is possible to compare the relative phase on each of the three modulations, and in so doing, obtain vernier readings on range measurements. In addition, the Doppler frequencies are used. The major advantage is that cyclic count is not necessary to locate missiles in space since each individual determination locates the missile exactly in the *X*, *Y*, and *Z* planes. Thus, spinning missiles do not give false cyclic counts and interrupted signals are not serious problems.

DORSAL POSITION. A position aft and on the upper side of an airframe or other body.

DOSE (DOSAGE). According to current usage, the radiation delivered to a specified area or volume or to the whole body. Units for dose specification are **roentgens** for *x*- or *γ*-rays, **reps** or **rems** (equivalent roentgens) for *β*-rays. The subject of dose units for particulate radiation and for very high energy *x*-rays has not been settled. In radiology the dose may be specified in air, on the skin, or at some depth beneath the surface; no statement of dose is complete without specification of location. The entire question of radiation dosage units is under consideration by the International Congress of Radiology, and it is expected that new units based on the energy absorbed in tissue will be adopted.

DOUBLE AMPLITUDE. Amplitude, peak-to-peak.

DOUBLE-BALANCED MODULATOR. Ring modulator.

DOUBLE-BASE POWDER PROPELLANT. Propellant, double-base powder.

DOUBLE-BASE PROPELLANT. Propellant, double-base.

DOUBLE MODULATION. Modulation, double.

DOUBLE SAMPLING. In production quality control, sampling inspection in which the inspection of the first sample leads to a decision to accept, to reject, or to take a second

sample and the examination of a second sample, when required, always leads to a decision to accept or to reject.

DOUBLE STAR. (See **binary star**.) There are numerous cases where two stars are so nearly in the same direction, as seen from the earth, that they appear as single stars to the unaided eye but may be separated into two components by the use of a telescope. Such a pair of stars is referred to as a double star. Double stars may be either one of two kinds. In cases where the two stars are only apparently close to each other (i.e., lie in approximately the same direction from the earth, but are separated by a great distance in the radial direction) the pair is known as an optical double. In the great majority of cases, however, the stars are actually close enough together to exert strong gravitational attractions on each other and are in **orbital** motion relative to each other. Such physically connected stars form what is known as a **binary star**.

DOUBLE-TAPER. Taper of an airfoil in plan form and in cross-section thickness from root to tip.

DOUBLE WEDGE. A supersonic airfoil cross-section consisting of two back-to-back triangles (or wedges). It is a preferred high-velocity supersonic airfoil section.

DOUBLER (CIRCUIT). A circuit for doubling a frequency. It is frequently used in missile **transponder** equipment. The transponder signal can by this means be readily distinguishable from the ground transmitter signal that activated it, but still be a known function of the original signal in case this is desired for some further use, as in **DOVAP**.

DOUBLET. (1) Two electrons which are shared by two atoms so as to form a non-polar valence bond. (2) A pair of spectral lines resulting from transitions between a common state and two states which differ only in total angular momentum (*J*), i.e., have identical values of orbital (*L*) and spin (*S*) angular momenta. (3) Two stationary states having common values of (*L*) and (*S*), but different values of (*J*). (4) A lens, particularly an achromat, having two components.

DOVAP. A contraction of the words *Doppler Velocity and Position*. It is a radio system

for obtaining missile trajectory data from the Doppler shift of a wave doubled and retransmitted from a missile in flight, as received at precisely spaced stations. The system uses a ground transmitter to excite a missile-borne receiver-transmitter (transponder) which accepts the ground signal and doubles it, retransmitting this doubled signal back to the ground. An array of three or more receivers on the ground takes the signal from the missile, and compares it with one from the master ground transmitter, which has been doubled for comparison purposes. These two signals are different in frequency by an amount proportional to the displacement of the missile during a reference period. The combination of the two frequencies (i.e., the ground reference frequency and the frequency from the missile transponder), results in the formation of beats, which are equal in frequency to the difference frequency between the two signals; this, in turn is a measure of the missile's radial velocity. In one form of recording, these beats are displayed on an oscilloscope, and pictures of them made by a 35mm movie camera the speed of which is synchronized to "sweep" the oscilloscope presentation, thus causing the scope deflections to be stretched into harmonic motion wave shapes. After the flight, the films are developed and the data appear as a series of sine waves. Very accurate recordings of time are made during the filming of the beats. These time records appear in a coded form along one edge of the DOVAP film. From these data a velocity and position history of the flight is computed and plotted or tabularized.

At slow missile speeds, DOVAP is not reliable. DOVAP is always weakest in measuring the vertical component of flight, since the component of such motion away from the recording station is small. The missile speed necessary for satisfactory results also depends upon the reference frequency used in the system. A high frequency is desirable since it produces beats more frequently. The equations which must be solved in order to determine position (X, Y, Z) in a three receiver Doppler system take the form:

$$u_i = \sqrt{x^2 + y^2 + z^2} \\ = \sqrt{(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2}$$

where u_i represents the integrated Doppler distance from the i^{th} station and x_i , y_i , and

z_i , represent the spatial coordinates of the i^{th} station relative to the ground transmitter. Each equation of the above form represents an ellipsoid of revolution, and the intersection of three such ellipsoids gives the desired position. There are many modifications of the basic Doppler technique resulting in systems such as TRIDOP, UDOP, EXTRADOP, DORAN and others.

DOVE. A U.S. Navy air-to-surface solid-propellant infrared homing rocket. It was developed by Eastman Kodak Company. It is also identified as the ASM-N-4 and ASM-N-5 (see **missile, guided**.)

DOWNRANGE. On a guided missile firing range, the direction from the launching point toward the impact point, i.e., in the direction of fire.

DOWN-TIME. The calendar time in which a missile or other system is not considered in condition to perform its required function.

DOWNWASH. (1) The downward deflection of air relative to the direction of motion of a missile, airfoil or other object. (2) A wing-tail aerodynamic interference effect which affects the lifting efficiency of aft surfaces when these are either controlling or stabilizing the missile about its center of gravity. This effect will cause positive trim angles of attack to exist with wing control types, even though the wing hub may be located on the overall missile center of gravity. The downwash produced by a given angle of attack increases as the aspect ratio is reduced. In subsonic aerodynamics the downwash of a two-dimensional wing is of the third order importance and is a small quantity. In supersonic flow the effects of the tip vortex must be confined to the **Mach cone**, and is also small but more important than in the subsonic case. Infinite **aspect ratio** wings have no downwash.

DOWNWASH ANGLE. The angle through which an air stream is deflected downward by a lifting surface. It is measured in a plane parallel to the plane of symmetry. It is the angular difference between the direction of the air ahead of the surface and the air behind the surface. The usual symbol for *downwash angle* is the Greek letter epsilon (ϵ).

D_p. Parasitic drag.

DPO. Development Planning Objective.

DRAG. (1) A resistive force exerted in a direction opposite to the direction of motion and parallel to the relative gas or air stream. (2) The effect of this resistive force. In a supersonic missile drag is generally resolved into three different components, (a) wave drag, (b) skin friction, and (c) drag due to normal force. The total of the wave drag (that is, drag forces due to pressures acting on the missile at zero angle of attack) and the skin friction is usually referred to as the "zero-lift drag," whereas the component of normal force acting in the airstream direction (and existing solely due to the resultant normal force) is referred to as the "lift-drag." The zero-lift drag is made up of the total pressure drag of the body, wings and tails, as well as the pressure effect of any protuberances, plus the skin friction acting over the entire body surfaces. The wave drag usually constitutes approximately one-half of the total zero-lift drag of a typical supersonic missile, the rest being made up by skin friction.

Brief definitions of various types of drag follow, in alphabetical order:

Additive drag. In ramjet theory, the drag on the stream tube between the shock and the cowl lip.

Area drag. (1) The ratio of drag to incompressible dynamic pressure, or to dynamic pressure. (2) The area of a flat plate producing the equivalent drag at a drag coefficient of unity. It is sometimes called "equivalent flatplate area."

Base drag. The component of drag caused by the reduction of pressure across the base of a missile or projectile to values below the ambient pressure. (See Tail drag below.)

Burner drag. Total drag due to the presence of a combustion system inside the burner (ramjet or turbojet). It includes the drag forces on the igniter, flame holder, combustion chamber wall, turbine, etc.

Diffuser drag. The drag acting on the diffuser cowl (ramjet). It includes the drag caused by the diffusion process and by the flow over the cowl.

Form drag. The drag due to the shape of the body. It is principally due to the cross-sectional area presented, but includes all com-

ponents due to the configuration; it excludes friction and lift effects.

Induced drag. That part of total drag induced by the lift.

Interference drag. Drag caused by the interference of the airflow around two closely-spaced objects, such as the wings of a biplane; or caused by the interference between the airflow around the fuselage and the normal flow around a wing attached to it.

Nose drag. The part of total drag due to the presence of the nose of the body with attendant local high pressures.

Parasite drag. The total drag less the induced drag of the wings. It includes all drag effects of surfaces not providing lift, such as drag due to turbulence.

Pressure drag. The integral of the component of the pressure force in the direction of motion, taken entirely around the body. In a general form it is the surface integral:

$$\int_S (P - P_0)_x ds$$

where P is the local pressure, P_0 is the free stream pressure, S is the surface area, and x as a subscript indicates that the component of pressure is along the direction of flight.

Profile drag. The difference between the total drag of a wing and its induced drag.

Skin friction drag. The component of drag tangent to the surface of a body, caused by air friction.

Tail drag or base drag. The drag component which results from the lowering of pressure along the tail of an aircraft, or the base of a missile projectile. Tail drag is used for objects with tail fins or other projections, and base drag for objects such as projectiles, that do not have tail fins or other stabilizing appendages. When a rocket is under power, the jet pressure on its tail prevents drag.

Total wing drag. A drag component consisting of the sum of the pressure drag, skin friction drag, and induced drag.

DRAG COEFFICIENT. Aerodynamic coefficients.

DRAG-WEIGHT RATIO. The ratio of the drag of a missile to its total weight.

DRIFT. (1) Random variations in direction. (2) The lateral divergence of a moving object from the projected line of its heading, due to aerodynamic forces, such as wind, the rotation of the object (e.g., a projectile), etc. (3) The lateral movement causing this divergence. (4) The angular measurement of this divergence. (5) Random variations in a characteristic of an electromagnetic wave or signal which are continuously in one direction or the other for periods of a second or more. (6) The change in direction of the axis of a gyroscope resulting from **precession**, apparent precession or both. (7) The displacement of the gimbals of a gyroscope due to bearing friction, weight of lead wire, anisoelastic effects, mass unbalance, etc. (8) An unbalance in a balanced **amplifier**, magnetic amplifier or other electronic device which occurs with time or change in operating conditions after the balance control has once been set.

DRIFT, ABSOLUTE. In a **magnetic amplifier**, absolute drift is expressed in terms of the input signal required to rebalance the amplifier. It may be measured in terms of watts, current, or ampere-turns.

DRIFT ANGLE. An angle measured from the heading of an aircraft, rocket, etc., to its track.

DRIFT CORRECTION ANGLE. A measure of the amount of turning necessary to make the track of an aircraft, rocket, etc., coincide with its heading or course, measured from the track to the heading.

DRIFT SPACE. In velocity-modulation tubes (see **tube**, **velocity-modulation**), the space between buncher and catcher.

DRIVEN ANTENNA. Antenna, directional.

DRIVEN ELEMENT. In an antenna array, the element or elements which are connected to the receiver (or transmitter).

DRIVER STAGE. The stage designed to supply the input signal power required by the last or final stage.

DRIVING POWER. The power which is required by an **amplifier** which operates in the positive grid region some portion of the time. For a class C amplifier, this power is very nearly equal to the average grid current times the crest value of the exciting voltage.

DRIZZLE. A very light rain in which numerous very small liquid droplets whose diameter is less than 0.5 mm and whose rate of fall is usually less than 3 m per sec.

DRL/UT. Defense Research Laboratory/The University of Texas; Austin, Texas.

DROGUE. A funnel-shaped surface towed behind an air vehicle for its drag effect. For example, a drogue chute is a funnel-shaped parachute deployed behind a landing aircraft to slow down its speed.

DRONE. A remotely controlled pilotless aircraft used as a target or to perform tasks hazardous to a human pilot: e.g., probe a nuclear cloud, survey enemy territory, target practice, etc.

DRONE, TARGET. Target drone.

DROP TEST. (1) An environmental linear acceleration test used to establish capability of equipment to withstand handling or drops in service. (2) A generic term categorizing tests in which the equipment is dropped in a tower, from a height, etc.

DRY-FUEL ROCKET. A rocket which uses a rapidly-burning fuel, and which is used especially as a booster.

DRUM SPEED. The number of scanning lines per minute in a facsimile system.

DRY RUN. A "dummy" test usually complete in detail except for actual operation of the equipment. It is used to develop crew skills and to assess readiness for a full scale test.

DRY STAND. A type of rocket launcher having a flame deflector which is not liquid-cooled.

DRY WEIGHT. The weight of a rocket vehicle, without its fuel and usually without its payload. The term is used especially for liquid-fuel rockets.

DUAL MODULATION. Modulation, dual.

DUCK. A U.S. Air Force air-to-air missile undergoing development by Fairchild.

DUCT. (1) In general, a tube or passage for conveying fluids. (2) In a jet engine, the passage conveying air from the air inlet to

the compressor. (3) A space within an electrical conduct to hold a cable.

DUCTED-FAN JET ENGINE. A turbojet engine in which a propeller or fan forces low-pressure air through ducts directly into the hot turbine exhaust at the turbine exhaust pressure.

DUCTED ROCKET. (1) A rocket mounted in a duct. (2) A rocket ramjet.

DUCTED SOLID PROPELLANT ROCKET. Rocket, ducted solid propellant.

DUD. (1) A missile which fails to operate during preparation, launching, or flight. (2) Armament which fails to operate.

DUMMY ANTENNA. A device having the inductance, capacity and resistance of an antenna in lumped form so that it can be used to replace an actual antenna, but of such a design that it does not radiate. It is used for coupling a signal generator to a radio receiver under test, or for dissipating the energy of a transmitter without external radiation.

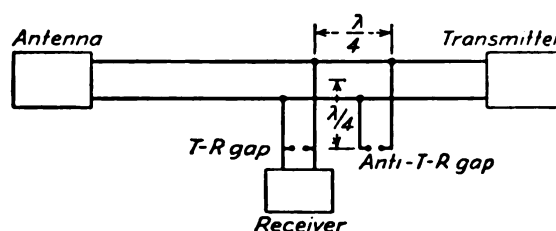
DUMMY LOAD. A component used during testing of either electrical or mechanical equipment to simulate the presence of a functional component not in use.

DUMP VALVE. A large-capacity valve in a fluid system used for very rapid emergency discharge. These valves are usually installed on fuel tanks.

DUNNITE. An explosive containing ammonium picrate as its primary constituent.

DUPLEX. Having two operational entities, separately identifiable but closely associated, and capable of performing two functions simultaneously.

DUPLEXERS (TRANSMIT-RECEIVE CIRCUITS). Circuits that make possible the use of the same antenna for both transmission and reception, by preventing the flow of damaging amounts of power to the receiver during transmission, without at the same time reducing excessively the input to the receiver during reception. Consider a basic circuit shown below. During reception, the open-circuited, quarter-wavelength branch containing the anti-T-R tube produces an effective short cir-



cuit at the junction of this branch and the transmitter branch, and therefore prevents loss of received power to the transmitter. A quarter of a wavelength away, at the junction of the antenna and receiver lines, this short circuit appears as an open circuit. During transmission, both tubes break down and short-circuit the lines in which they are placed. Since the short circuits occur at a distance of a quarter-wavelength from the transmitter-antenna line, the receiver and anti-T-R lines present an infinite (ideally) impedance across the transmitter-antenna line, and therefore divert negligible power. It is possible to use only the T-R tube but this necessitates careful adjustment of the transmitter-to-junction distance which, in the scheme shown, is not a critical factor. (See transmit-receive switch.)

DUTY CYCLE. (1) The time interval consumed by a device on intermittent duty in starting, running, stopping, and idling. (2) The ratio of this time interval to the total time of one operating cycle. (3) The ratio of the pulse width to the interval between like portions of successive pulses.

DUTY FACTOR. In a pulse carrier composed of pulses that recur at regular intervals, the product of the pulse duration and the pulse-repetition frequency.

DX. Distant reception.

Dy. Dysprosium.

DYNAJET. A trade name for a small rocket commercially available for amateur or other experimenters.

DYNAMIC BALANCE. In a (moving) system whose center of gravity does not coincide with the reactions, the attainment of balance by addition of counterbalances, e.g., masses to a rotating machine to off-set an unbalanced torque.

DYNAMIC BEHAVIOR. Performance of a moving system or entity with time.

DYNAMIC FACTOR. The ratio between the load carried by any part of an aircraft when accelerating and the corresponding basic load.

DYNAMIC LIFT. The added lift obtained by a sudden change in the angle of attack of an air vehicle.

DYNAMIC PICKUP. A pickup utilizing a coil positioned in a constant magnetic field and driven by the stylus.

DYNAMIC PRESSURE (TOTAL HEAD). The pressure that a moving fluid would attain if it were brought to rest by isentropic flow up a pressure gradient. For an incompressible fluid, the dynamic pressure is the sum of the local pressure and the kinetic energy per unit volume.

DYNAMIC STABILITY. Stability, dynamic.

DYNAMIC VISCOSITY. The viscosity of a fluid resulting from its motion.

DYNAMICS. The science of the motions of bodies (systems of particles) under the action of forces.

DYNAMITE. Nitroglycerine absorbed in infusorial earth. In the United States dynamites now contain 15-60% nitroglycerine with sodium nitrate, carbon, and sometimes other additives.

DYNAMOMETER. (1) A test device used to measure mechanical power. (2) In electronic meter movements, a dynamometer movement uses an electromagnet rather than a permanent magnet (as in the case of a D'Arsonval movement).

DYNAMOTOR. A double-armature rotating electrical machine. One of the armatures is wound for low voltage direct current, and serves as a motor armature. The other armature is wound for a high d-c voltage and serves as a generator winding. The machine is used for supplying plate voltage to portable radio equipment, being operated from storage batteries on the motor end and supplying the high voltage d-c from the generator winding.

DYNA-SOAR. A U.S.A.F. manned boost-glide rocket program announced in 1958. In June 1958 the U.S. Air Force indicated that the Glenn Martin Company and the Boeing Airplane Company, would head competitive teams for Dyna-Soar. The program called for long-range manned flights to intercontinental distances, followed by eventual Earth satellite orbits.

DYNASTAT. The trade name for a commercially available d-c to d-c solid state power supply.

DYNATRON. A four-electrode vacuum tube so designed that secondary emission of electrons from the plate causes the plate current to decrease as plate voltage is increased, giving a negative resistance characteristic. It is used in oscillator circuits.

DYNE. The unit of force in the metric system. It is defined as the force necessary to accelerate one gram mass one centimeter per second per second. (See **units and dimensions**.)

DYNODE. (1) An additional electrode in a photomultiplier tube, which undergoes secondary emission upon bombardment by photoelectrons, and thus effects amplification. (2) A photomultiplier tube having one or more dynodes (1).

DYOTRON. A microwave oscillator tube (see **tube, microwave oscillator**) containing a single cavity and three electrodes.

DYSBARISM. A disturbance in the human body, often occurring with changes in altitude, resulting from a pressure differential between the ambient barometric pressure and the pressures of dissolved and free gases within the body tissues, fluids, and cavities.

DYSPROSIUM. Rare earth metallic element. Symbol Dy. Atomic number 66.

DZUS FASTENER. The trade name for a quick-operating metal fastener used on inspection or access panels. The fastener consists of a flush-mounted screw with a hook projection which can be shaped to form a spring-loaded fastener to hold another object.

E

E. (1) Symbol for an electron or its electric charge (e). (2) The number e (see **e, the number**), the natural logarithmic (Napierian) base (e). (3) Electromotive force (ξ or E). (4) Electrode potential (ξ or E). (5) The Einstein, a unit of energy (E). (6) Total energy (E). (7) Kinetic energy (E_k). (8) Potential energy (E_p). (9) Energy of vibration (E_v). (10) Electric field strength (E). (11) Illuminance (E). (12) Young's modulus of elasticity (E). (13) Coefficient of resilience or restitution (e). (14) Exit (e). (15) Ostwald's efficiency factor (E).

E & ST. Employment and Suitability Test. Corresponding missile test for an Operational Suitability Test for aircraft.

e, the number. In mathematics, a very useful irrational and transcendental number defined by:

$$e = \lim_{n \rightarrow \infty} \left(1 + \frac{1}{n}\right)^n$$

which may be represented by the infinite series:

$$e = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \dots + \frac{1}{n!}$$

It has the approximate value of 2.7182818285 and is used as the base of natural logarithms (which are also called Napierian or hyperbolic logarithms).

E LAYER. A layer of the **ionosphere** that persists both day and night from about 55 miles to 85 miles, i.e., immediately below the F layer. Sometimes called the "Heaviside layer," or the "Kennelly-Heaviside layer."

E REGION. E Layer.

EAFB. Edwards Air Force Base; Edwards, California—Eglin Air Force Base; Valparaiso, Florida.

EAGLE. A projected missile for air-to-ground and air-to-air use.

EAPD. Eastern Air Procurement District.

EARLY BIRD. A missile which arrives at the intersection of the missile-target trajectories prior to the arrival of the target.

EARLY (BURST). Warhead detonation during the period after the S and A but before target detection.

EARLY WARNING SYSTEM. Part of an air defense system usually comprising search radars, whose function is to detect and identify attacking enemy aircraft in time to permit effective use of the system's air defense weapons.

EARTH. (See tables of planetary data in the article on **Planet**.) The earth is third planet in point of distance from the sun and is unique in being the only planet which is known to carry an **atmosphere** capable of supporting human life. Angular velocity of the earth in orbit about the sun = 1.991×10^{-7} radians/second. The speed of revolution of the earth about the sun varies (greater in January than in July) with an average of approximately 66,000 miles per hour. The figure of the earth (see **earth, figure of the**) is not known with mathematical precision but is generally an oblate spheroid. If the earth were a perfect sphere, a degree of latitude would have the same linear length everywhere. Observations show that a degree of astronomic latitude is longer the higher the latitude on the earth. Accurate measurements indicate a difference of 26.70 miles between the equatorial and polar diameters of the earth, the polar being the shorter. The earth has four principal motions: rotation on its polar axis once per day; revolution about the sun once a year; precession about the ecliptic axis once each 25,800 years, yielding a conical shaped motion of the earth's axis of 50.2 seconds of arc each year; and space motion along with the entire solar system. The United States uses the Clarke 1866 spheroid as the geodetic standard

for mapping. Approximately 71% of the earth's surface is water. The total mass of the earth is 5.98×10^{27} grams. It is the fifth largest planet in the solar system. (See also **gravity**, **geoid**, **latitude**, **longitude**, **planet**, **spheroid**.)

EARTH AXIS. Any one of a set of mutually perpendicular reference axes established with the upright axis (the Z-axis) pointing to the center of the earth, used in determining the position or performance of an aircraft or other body in flight. The earth axes may remain fixed or may move with the aircraft or other object.

EARTH, EFFECTIVE RADIUS OF THE. Effective radius of the earth.

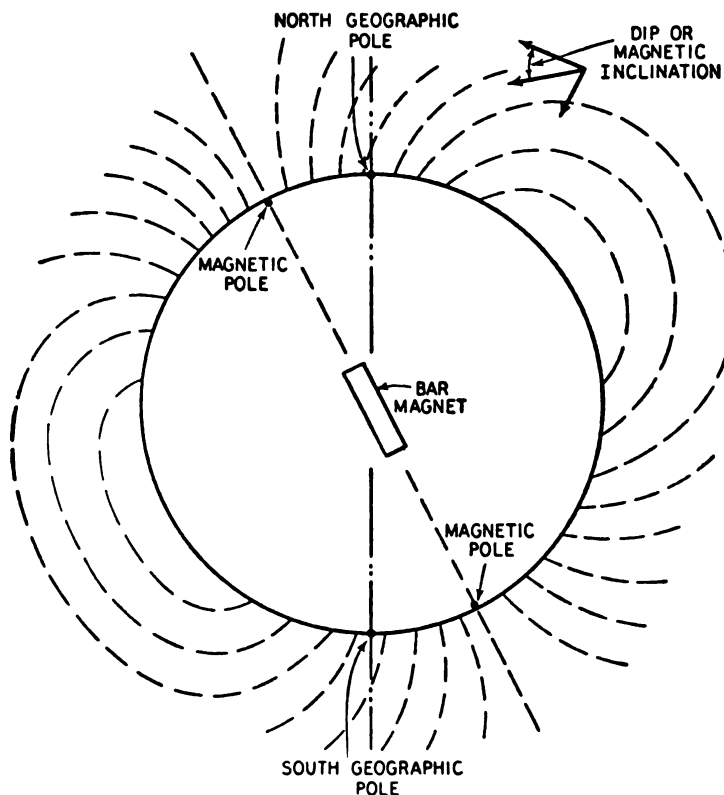
EARTH, FIGURE OF THE. The exact shape and size of the earth, as determined by terrestrial surveys in conjunction with the observation of celestial bodies from various points on the surface, or in conjunction with measurements of the acceleration due to gravity. The earth is approximated closely by an oblate spheroid, with an equatorial radius

of 6.378×10^6 meters and a polar radius of 6.357×10^6 meters.

EARTH INDUCTOR. A coil rotated in the earth's magnetic field to permit determination of the field's strength.

EARTH INDUCTOR COMPASS. An induction compass. (See **compass**, **induction**.)

EARTH MAGNETIC FIELD. (See figure.) The existence of the earth's magnetic field is apparent from a number of phenomena, one of the longest-known being the orientation of magnets which are supported so they are free to move. The most widely used application of this phenomenon is, of course, the magnetic **compass**. The orientation of the earth's magnetic field, that is, the direction of its magnetic poles, as indicated by a compass needle, or other suspended magnets, has shifted considerably over the centuries and continues to drift, the north magnetic pole being located presently in east-central Canada. Short term variations in the earth's magnetic field occur, one of the phenomena causing them, or with which they can be correlated to some degree, being **sunspots** (solar eruptions).



The earth's magnetic field.

In investigating the magnetic field of the earth, three measurements commonly made are: (1) magnitude of the horizontal component of the total magnetic intensity, (2) angle that the horizontal component of magnetic intensity makes with the geographical meridian (**declination**), (3) angle between the total intensity and horizontal component of the total intensity (**dip**).

The variations in the earth's magnetic field may be classified as regular changes, unpredictable changes, and anomalies. The regular changes are sometimes subclassified as secular changes (occurring over a long period of the order of a millenium) annual changes, and diurnal changes. The unpredictable changes (magnetic storms) have, as stated above, been correlated with sunspot activity. The anomalies have been subclassified into continental, regional and local anomalies.

The various magnetic lines which appear on maps and charts connect points of equal magnetic properties, which, while subject to the changes mentioned, can be used for navigational purposes, especially if modified from time to time by newly-published information. There are a number of such lines. The *magnetic equator* joins points on the earth's surface where a magnetic compass has zero dip. *Isoclinic lines* join points of equal magnetic dip. *Isogonic lines* join points of equal magnetic declination, while *agonic lines* join points of zero magnetic declination. *Isodynamic lines* join points of equal horizontal magnetic intensity.

EARTH, NON-ROTATING. Non-rotating earth.

EARTH PENDULUM (84 MIN. PENDULUM; SCHULER PENDULUM). A pendulum with a length equal to radius of the earth and a natural period of 84 minutes. It has the property of being insensitive to earth's rotation. Pendulum systems having the same period are similarly insensitive and are therefore much used in gyro reference systems.

$$T = 2\pi \sqrt{\frac{L}{g}} = 2\pi \sqrt{\frac{3963 \times 5280}{32 \times 3600}} = 84 \text{ min}$$

EARTH'S RATE. The apparent angular motion of a space-stabilized **gyroscope** caused by the earth turning on its axis (at 15° per hour). Gyro drift is usually measured as a

fraction of earth's rate; otherwise in degrees per hour.

EARTH SATELLITE. Satellite, earth.

EBULLISM. The formation of water vapor bubbles in the tissues caused by boiling of body fluids.

e.c. Cathode voltage.

ECCENTRIC. Of an orbit, exhibiting eccentricity.

ECCENTRICITY. The constant ratio of the distance from a fixed point on an (ellipse, parabola or hyperbola) to its focus, to the distance of that point from the directrix.

ECCLES-JORDAN CIRCUIT. Flip-flop circuit.

ECCM. Electronic Counter-Countermeasure(s).

ECCO. A type of solid propellant binder, consisting of ethyl cellulose and castor oil. The name is derived from the first letters of the names of these two materials.

ECHO. A wave which has been reflected at one or more points in the transmission medium, or otherwise returned with sufficient magnitude and delay to be perceived in some manner as a wave distinct from that directly transmitted. More specifically, the signal returned from a target when illuminated by a radar.

ECHO BOX. A cavity resonator, having small damping, which is energized by pulses of energy radiated from a nearby radar antenna, or is picked up by a probe in a waveguide. It is used as a test device to check the overall performance of a radar system by echoing transmitted signals into the radar receiver to check its functioning.

ECHO DEPTH SOUNDING. The determination of the depth of water by the measurement of the time interval required for a sonic or supersonic pulse to reach the transmission point after being reflected from the bottom.

ECHO, FLUTTER. A rapid succession of reflected pulses resulting from a single initial pulse.

ECHO LEVEL. A quantity defined by the ratio:

$$E = 10 \log \frac{I_e}{I_r}$$

where E is the echo level in decibels, I_e is the intensity of returning sound signal, and I_r is the reference intensity.

ECHO RANGING. The determination of the distance and direction of underwater objects by the same process used in **echo depth sounding**. Commonly called **sonar**.

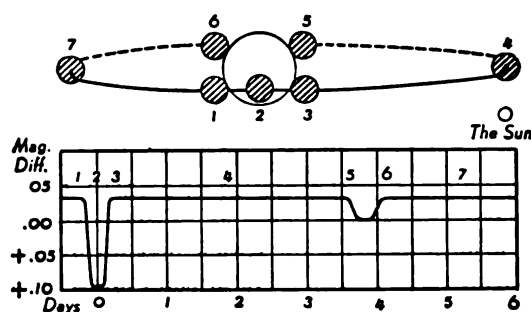
ECHOING AREA OF TARGET, EFFECTIVE. In radar technology, the area of an hypothetical target, normal to the incident beam, which re-radiates equally in all directions all the energy incident on it, and produces at the receiver a signal equal to that produced by the actual target. The value of A_e for an actual target depends on many factors, and can only be found empirically. For an average aircraft it is of the order of 1 to 10 square meters.

ECL. Equipment component list.

ECLIPSES. The term eclipse is applied to the darkening of a heavenly body due to the presence of another object. There are two cases to be considered, depending upon whether the object in question is self-luminous or is shining by reflected light. In the case of a self-luminous object, an eclipse or **occultation** takes place when an opaque object passes between the object and the observer. An object which is shining by reflected light is eclipsed when an opaque body passes between the object under consideration and its source of light. Eclipses of the first type are illustrated by an eclipse of the sun where the moon passes between the sun and the observer, in the case of an occultation of a star by the moon, and in the cases of **eclipsing binary stars**. A typical example of the second case is found in an eclipse of the moon where the earth passes between the sun and the moon.

ECLIPSING BINARY. When the orbit plane of a **binary star** lies so nearly in the line of sight of the observer that the components undergo mutual **eclipses** the object is known as an eclipsing binary. In case the binary is also a spectroscopic binary and the **parallax** of the system is known we have one of the

most valuable specimens for stellar analysis. Eclipsing binaries are **variable stars**, not because the light of the individual components vary, but because of the eclipses. The most notable of the eclipsing binaries is the star Algol (β Persei), so named the "demon star" by the Arabs in all probability because they noticed the variation in light.



Apparent relative orbit and light curve of the eclipsing binary 1H. Cassiopeiae. (Curve and orbit determined by Joel Stebbins from his observations with the photoelectric photometer at the University of Illinois.)

The **light curve** of an eclipsing binary is characterized by periods of practically constant light with periodic drops in intensity. In the figure we have a characteristic light curve of such an object. In this case the eclipse of the larger and brighter primary star by the secondary is annular, while the eclipse of the secondary by the primary is total.

ECLIPTIC. The great circle cut out on the celestial sphere by the plane containing the orbit of the earth is known as the ecliptic. The ecliptic is the fundamental plane for the system of **spherical coordinates** in which celestial **latitude** and **longitude** are measured. The ecliptic is also the reference plane to which the planes of the orbits of all the members of the **solar system** are referred.

The plane of the ecliptic is inclined to the plane of the **equator** by an angle of approximately $23^\circ.5$, known as the obliquity of the ecliptic. The two planes intersect in a line known as the line of nodes. The points where this line of nodes intersects the celestial sphere are known as the equinoxes. The apparent motion of the sun in the ecliptic about the earth, due to the actual motion of the earth in its orbit, causes the sun to pass through each one of the equinoxes once each year. The point where the sun crosses the

equator from south to north is known as the **vernal equinox**, and the opposite extremity of the line of nodes is the autumnal equinox. Due to **precession** the direction of the line of nodes is continually changing relative to the stars. At present the vernal equinox is in the constellation of **Pisces** and is continually moving along the ecliptic in a direction to the annual motion of the sun at such a rate that it will complete one revolution of the ecliptic in approximately 25,000 years.

ECM. Electronic countermeasures.

ECOSPHERE. That region of the atmosphere from the surface of the earth to approximately 13,000 feet. It is the portion of the atmosphere within which normal unaided breathing is possible. It is sometimes called the physiological atmosphere.

ECP. Engineering Change Proposal.

EDDY. A current of air or other fluid that flows contrary to the main stream, especially a small vortex of air that flows counter to the main airflow.

EDDY CURRENT(S). Currents set up in a substance by variation of an applied magnetic field. Eddy currents result in both power loss and reduction of magnetic flux. Transformer cores and dynamo frames are laminated to break up the iron structure into thin, insulated layers, to reduce eddy currents. Eddy currents are used in induction heating and in various **damping** devices.

EDPC. Electronic Data Processing Center.

EDPS. Electronic Data Processing System. Part of the Air Materiel Command network for logistics support.

EDVAC. A high speed digital computer located at the Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland.

EE GUIDED ROCKET. A 1954 British (English Electric Company), rocket vehicle designed as an antiaircraft missile. It was designed for an operating ceiling of 50,000 feet using a 4,400 pound thrust visol-nitric acid sustainer with solid rocket boost (3,300 pounds for 7 seconds). It carried 1,050 pounds payload to a distance of about 25 miles at a speed of about 900 miles per hour.

Weight was 4,350 pounds plus about 800 pounds additional for booster. Guidance was radio command.

EFFECTIVE ANGLE OF ATTACK. That part of a given **angle of attack** that lies between the chord of an airfoil and a line representing the resultant velocity of the disturbed airflow.

EFFECTIVE ANGULAR VELOCITY. The effective angular velocity at a point is the root mean square value of the instantaneous **angular velocity** over a complete cycle at the point. The unit is the radian per second.

EFFECTIVE AREA. (1) The area of a wing (or other airfoil) plus that portion of the area of the fuselage which is effective in producing lift. (2) The area of effective destruction of an explosive. (3) Of an antenna, the square of the wavelength times the **power gain** (or **directive gain**) in a specified direction, and divided by 4π . When power gain is used, the effective area is that for power reception; when directive gain is used, the effective area is that for **directivity**.

EFFECTIVE ASPECT RATIO. In aerodynamic theory, the **aspect ratio** of an airfoil of elliptical plan form that, for the same lift coefficient (see **coefficient, of lift**) has the same induced-drag coefficient (see **coefficient of drag**) as the airfoil or combination of airfoils under consideration.

EFFECTIVE ATMOSPHERE. The portion of the **atmosphere** which has a significant effect upon a particular process. The term has been used especially with reference to the motion of an artificial satellite (see **satellite, artificial**) where the effect of importance is that upon the orbital motion of the satellite due to atmospheric friction and inertia. In this sense, the effective atmosphere is the region of the atmosphere below an altitude of 120 miles, since above that the density of the air is so small that it does not measurably affect the orbit of the satellite.

EFFECTIVE BAND WIDTH. Band width, effective.

EFFECTIVE CUTOFF FREQUENCY. Cutoff frequency, effective.

EFFECTIVE EXHAUST VELOCITY. In jet propulsion terminology, the thrust divided

by the mass of propellant flowing per second of time. It appears in the equations:

$$c = \frac{F}{w/g} \quad \text{or}$$

$$c = \frac{F}{\dot{m}} = gI_{sp} = \frac{Fg}{\dot{w}} = c^*C_f = \eta_v c_{th}$$

$$= V_e + \frac{A_e}{\dot{m}} (p_e - p_0)$$

where c is the effective exhaust velocity, F is the thrust, w is the weight of propellant, g is the acceleration of gravity, \dot{m} is the mass flow through motor, I_{sp} is the specific impulse, \dot{w} is the weight flow of propellant through the motor, c^* is the characteristic velocity, C_f is the thrust coefficient, η_v is the motor velocity correction factor, and $c_{th} = \lambda V_e$, where λ is the nozzle correction factor, and V_e is the exhaust velocity. A_e is the exit area, p_e is the exhaust pressure, and p_0 is the ambient pressure.

The theoretical effective exhaust velocity is given by the equation:

$$c_{th} = \lambda V_e + (p_e - p_0) \frac{A_e}{\dot{m}_{th}}$$

Theoretical and actual values differ because of the losses due to friction and heat transfer. Logical theoretical values of c might range between 3300-9000 feet/second. A typical actual value is on the order of 6300 feet/second. The effective exhaust velocity is an experimentally determined value, but it is not the exhaust velocity actually attained by the motor. In the flow of gas through a rocket nozzle, variations occur in the thermodynamic parameters because of friction, of the continued combustion of the propellant, and of the secondary effects of compressible fluid flow, such as shock waves. For these reasons the effective exhaust velocity is used primarily in solving actual problems. (See **exhaust velocity**.)

EFFECTIVE FORCE (EFFECTIVE MECHANOMOTIVE FORCE). The root mean square of the instantaneous force (see **force**, **instantaneous**) over a complete cycle. The unit is the dyne.

EFFECTIVE HEIGHT (ANTENNA). In its former usage, this term was applied to the actual height of the vertical section, multiplied by the ratio of the average current in

that section, to the input current. In its present usage, this term means the height of the antenna center of radiation above the effective ground level. For an antenna with symmetrical current distribution, the center of radiation is the center of distribution. For an antenna with asymmetrical current distribution, the center of radiation is the center of current moments when viewed from directions near the direction of maximum radiation.

EFFECTIVE RADIUS OF THE EARTH.

A value for the radius of the earth used instead of the geographical radius to correct for atmospheric refraction. Under conditions of standard refraction the effective radius of the earth is 8.5×10^6 meters, as contrasted with the geographical mean radius of approximately 6.4×10^6 meters. Thus a radio wave propagated through the atmosphere behaves as if the earth were $\frac{4}{3}$ its actual size insofar as refraction is concerned; the phenomenon is particularly noticeable as propagation beyond the actual horizon.

EFFECTIVE SOUND PRESSURE. Sound (acoustomotive) pressure.

EFFECTIVE STATIC STABILITY. Stability, effective static.

EFFECTIVE VALUE (OF AN ELECTRICAL QUANTITY). The root-mean-square of the current, potential difference, or power in an electrical circuit in which the current is alternating or otherwise varying with time. The effective value of a quantity which varies sinusoidally is $1/\sqrt{2}$ times the amplitude.

EFFICIENCY. The general significance of this term as applied to a device or machine in which either a transfer of energy from one place to another, or a transformation of energy from one form to another occurs, may be expressed as the ratio of useful output to total input of energy or of power. The ratio is customarily expressed as a percentage. If a d-c motor, for example, is operating on 4 amperes at 100 volts (the power input is 400 watts), and if the motor actually delivers only 280 watts of mechanical power, its efficiency at that load is 280 watts ÷ 400 watts, or 70 per cent. In general, the efficiency of a machine varies somewhat with the conditions under which it operates. Usually there is a

load for which the efficiency is a maximum. This may be illustrated by a heavy block-and-tackle. For a small load the efficiency would be very low, because of power wasted in bending the ropes; for an excessive load it would again be low, on account of the large friction which would then develop; while for intermediate loads, higher efficiencies would prevail.

The concept may be extended to other than purely mechanical systems. Thus, the efficiency of an electric lamp may be expressed in candles of lumens of luminous flux (output) per watt of electric power (input); or that of an automobile horn in watts of acoustic power (noise) per watt of electric input. Various types of heat engine exhibit different thermodynamic efficiencies, i.e., the ratio of the work derived in the engine to the heat energy applied to it. (See **thermal efficiency**.)

EFFICIENCY OF ROCKET MOTOR. The efficiency of a rocket motor may be expressed as the product of a number of factors. One relationship between these factors is the following:

$$\eta = \eta_d \eta_F \eta_v$$

where η is the (overall) efficiency of the motor, η_d is the discharge correction factor, η_F is the thrust correction factor and η_v is the velocity correction factor. These factors are expressed, in turn, by the following relationships:

$$\eta_d = (dm/dt)/(dm/dt)_{th}$$

$$\eta_F = F/F_{th} = \eta_v/\eta_d$$

$$\eta_v = c/c_{th}$$

where (dm/dt) is the mass flow rate, F is the thrust, c is the effective exhaust velocity, and subscript th denotes the theoretical values. The ideal efficiency of a rocket motor is found from the relationship

$$\eta_i = 1 - (p_e/p_c)^{\frac{\gamma-1}{\gamma}} = 1 - T_e/T_c$$

where η_i is the ideal efficiency, P_e is the exhaust pressure, P_c is the chamber pressure, γ is the ratio of specific heats, T_e is the exhaust temperature and T_c is the chamber temperature. The efficiency of any jet engine can be regarded as the product of its thermal efficiency, η_T , its mechanical efficiency, η_M , and its propulsive efficiency, η_P , provided that

these terms are defined as follows:

$$\eta_T = \text{thermal efficiency}$$

$$= \frac{\text{Input to the nozzle}}{\text{Energy in the fuel}}$$

$$\eta_M = \text{mechanical efficiency}$$

$$= \frac{\text{Energy available for propulsion}}{\text{Input to nozzle}}$$

$$\eta_P = \text{propulsive efficiency}$$

$$= \frac{\text{Propulsive work}}{\text{Energy available for propulsion}}$$

EFFUSER. (1) A duct which conducts a working fluid from within a system to its outer parts, or to the external atmosphere, frequently so designed as to accelerate the flow. (2) A nozzle.

EGLIN AIR FORCE BASE. A U.S. Air Force inland bombing range near Pensacola, Florida. The range was used for bomb and aircraft ordnance testing but is being expanded for missile testing.

EIGHTY-FOUR MINUTE OSCILLATION. Earth pendulum.

EINSTEIN FORMULA FOR MASS-ENERGY EQUIVALENCE. The equivalence of a quantity of mass m and a quantity of energy E by the formula $E = mc^2$, where c is the speed of light in *vacuo*. (See **mass-energy equivalence**.)

EINSTEIN SHIFT. A shift toward the red in the spectral lines of light, this shift resulting from a slight reduction in frequency of the light as it emerges from a strong gravitational field, such as that of a dense star.

EKTRON. A registered trademark of the Eastman-Kodak Company. It is a photo-sensitive detector (resistor) using lead sulfide as a sensitive element. It is sensitive to infrared radiation and to x-rays down to a few Angstroms in wavelength. Its sensitivity increases with decreasing temperature.

ELASTIC COLLISION. Collision, elastic.

ELASTIC LIMIT. The maximum unit stress which can be obtained in a structural material without causing a permanent deformation.

ELASTICITY. The property whereby a body, when deformed, automatically recovers

its normal configuration as the deforming forces are removed. Each of its several types is probably due to the action of intermolecular forces which are in equilibrium only for certain configurations.

Deformation or, more briefly, strain is of various kinds; in each case its measure is a certain abstract ratio. For example, the elongation of a rod under tension is expressed as the ratio of the increase in length to the unstretched length. Linear compression is the reverse of elongation. They are both accompanied by a fractional change in diameter, the ratio of which to the elongation is called the Poisson ratio. Shear is a strain involving change of shape, such that an imaginary

cube traced in the unstrained material becomes a rhombic prism. The measure of shear is the tangent of the angle through which the oblique edges have been made to depart from their original perpendicular direction. Volume strain is the ratio of a decrease in volume to the normal volume. Flexure or bending, and torsion or twisting, are combinations of these more elementary strains. A straight rod bent into a plane curve undergoes elongation on the convex side and linear compression on the concave side, while there is an intermediate neutral layer which suffers neither.

For every strain there arises, in an elastic substance, a corresponding stress, which represents the tendency of the substance to recover its normal condition. Stress is expressed in units of force per unit area. Tensile stress, for example, is the ratio of the force of tension to the normal cross-section of the rod subjected to it. Shearing stress is the force tending to push one layer of the material past the adjacent layer, per unit area of the layers. Pressure, expressed in like units, is the stress corresponding to volume compression, etc.

For each type of strain and stress there is a modulus, which is the ratio of the stress to the corresponding strain. In the case of elongation or linear compression, it is commonly called the Young modulus; we also have the bulk modulus and the shear modulus or rigidity.

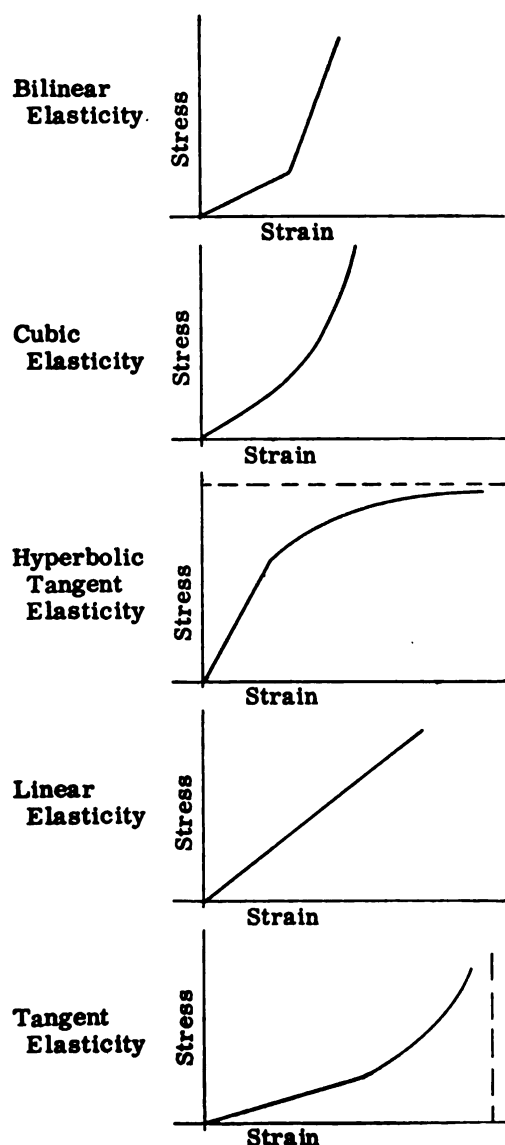
In engineering design the Young modulus is used for tension and compression and the rigidity modulus for shear, as in torsion springs. (See types of elasticity relations in figure, and in entries following.)

ELASTICITY, ANOMALOUS. The elasticity of a material in which the stress-strain relationship is not represented by an easily-derived mathematical expression.

ELASTICITY, BILINEAR. The elasticity of a material in which the stress-strain relationship is expressed mathematically by two linear functions.

ELASTICITY, CUBIC. The elasticity of a material in which the stress-strain relationship is expressed mathematically by a cubic function.

ELASTICITY, HYPERBOLIC TANGENT. The elasticity of a material in which the



Types of elasticity relations.

stress-strain relationship is expressed mathematically by a hyperbolic tangent function.

ELASTICITY, LINEAR. The elasticity of a material in which the stress-strain relationship is expressed mathematically by a linear function.

ELASTICITY, TANGENT. The elasticity of a material in which stress-strain relationship is expressed mathematically by a tangent function.

ELASTICIZER. An elastic substance or fuel used in a solid rocket propellant, especially to prevent cracking of the propellant grain and to bind it to the combustion-chamber case.

ELECTRA. (1) A German **continuous-wave** navigation system using radio beacons providing multilobe equisignal patterns. (2) A jet transport manufactured by Lockheed Aircraft Corp. An **ASW** version is under development for the U.S. Navy; its model designation is P3V.

ELECTRIC(AL) DEGREE. One 360th part of the angle represented by one complete cycle of alternating current. Mechanical or geometrical degrees are not necessarily equal to electrical degrees. For example, in an a-c generator one electrical degree is one 360th part of the angle subtended by the axis of the generator between two consecutive field poles of like polarity. In electronic equipment used to measure missile trajectories by phase comparison of the same signal arriving at two different stations of known geometry, the electrical degree is proportional to a lateral displacement of the missile from the centerline between the two stations. The measure in geometrical degrees of this displacement varies with the number of electrical degrees of phase shift, but in different amounts for each electrical degree of shift, depending upon the range of the missile.

ELECTRIC FEEDBACK. In magnetic amplifier terminology, **feedback** through an electrically conductive network, as differentiated from feedback produced by currents in windings having coupling to the control windings (magnetic feedback).

ELECTRIC FIELD. Electromagnetic field.

ELECTRIC FIELD VECTOR. The force on a stationary positive charge per unit charge.

It may be measured in newtons per coulomb or in volts per meter. The term is also called electric field intensity.

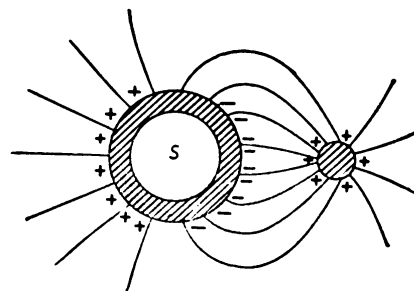
ELECTRIC(AL) MODULATION. The modulation of a carrier by the signal current in any form of electrical or electronic modulator.

ELECTRIC MOTOR. Motor, electric.

ELECTRIC(AL) NOISE. Noise, electrical.

ELECTRIC RING. A theoretical current flowing around the earth with a maximum value in the equatorial plane at a distance of about 7 times the radius of the earth. It is believed to superimpose its own magnetic field on the earth's field, and is thought to modify the magnetic storms due to high solar activity. It is also called the "equatorial electrojet."

ELECTRIC SCREENING. The experiments of Faraday revealed that any region completely enclosed by metal or other good **conductor**, however thin, is entirely free from **electrostatic** fields due to anything going on outside the enclosure. Conductors are impervious to electric fields, because the free **electrons** in the conducting shell surrounding the enclosure instantly adjust themselves so as to offset the effect of any electrostatic force that would otherwise penetrate the interior. Even a cage of fairly coarse screen wire is quite effective. Since **electromagnetic radiation** involves electric fields, we have here an explanation of why metals are opaque to it.



Showing induction and external field. Space S is completely shielded.

The screening effect of conductors is utilized in many kinds of electrical apparatus, as by enclosing electroscopes and the wires leading to them in metal cases or conduits, the placing of metal covers over radio tubes, etc. Whole buildings are sometimes covered with sheet

iron to prevent induction sparks due to lighting from setting fire to inflammable contents, such as gasoline or explosives.

ELECTRICAL PROPULSION VEHICLE.

A model of a hypothetical space craft recently released by the National Advisory Committee for Aeronautics. The illustration facing Page 539 shows a nuclear reactor (at tip), and then, from left to right, a neutron shield, gamma ray shield, propellant storage, turbo generating equipment for working fluid and, at far right, two crew cabins, a landing vehicle similar to the manned hemisphere, and a ring-shaped propellant accelerator.

ELECTRICAL SYSTEM. A system for the transmission of electrical currents, consisting of one or all of the electrical elements: resistance, inductance and capacitance which, added vectorially, constitute impedance.

ELECTRICAL UNITS. Units and dimensions.

ELECTRODE. In an electric circuit, part of which is composed of other than the usual conductor of copper, or other metal, the terminal connecting the conventional conductor and the conducting substances is an electrode. Examples of electrodes are to be found in the electric battery, where they dip in the electrolyte; the electric furnace, where the electrodes connect the external circuit with the heating arc; and the metallic elements in thermionic tubes and gas-discharge devices, and in semiconductor devices, where they perform one or more of the functions of emitting, collecting or controlling by an electric field the movements of electrons and ions.

ELECTRODE, DEFLECTING. An electrode the potential of which provides an electric field to produce deflection of a beam of electrons or other charged particles.

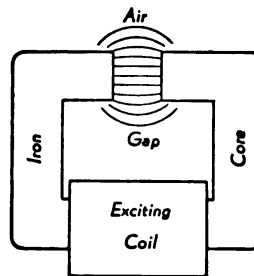
ELECTROFORMING. The electrolytic deposition of metal upon a conducting mold, to make a desired metal object, such as precision tubing or medals. The mold is often of graphite-coated wax, so that it can be removed by melting. (See **electroplating**.)

ELECTROJET. A theoretical layer of ionized particles believed to have motion relative to the Earth and caused by solar radiation.

ELECTROLYTE. (1) Any substance whose solutions have the property of conducting the electric current. All soluble acids, bases, and salts are electrolytes. (2) A solution which conducts the electric current.

ELECTROLYTIC RECTIFIER. An electrolytic system which converts alternating current to direct current. It consists essentially of a combination of two electrodes and an electrolyte which produces a polarizing film on one of the electrodes that practically bars the flow of current into it from the solution, while freely permitting flow in the opposite direction. Groups of these cells may be arranged to utilize both halves of the alternating-current cycle.

ELECTROMAGNET. A magnet whose field is produced by an electric current, and which is largely demagnetized upon cessation of the current. In order to obtain the strongest field possible, highly permeable soft iron or steel is employed for the core of electromagnets.



Sketch of electromagnet having two poles; one of a large variety of designs.

In an electromagnet the current flows through a solenoid, which is a conductor wound in the form of a helix, and which produces a strong magnetic field coaxial with the helix. The core is placed inside the helix in order to give a magnetic path of the least reluctance.

ELECTROMAGNETIC DEFLECTION COIL. The coil used to produce electromagnetic deflection. In cathode-ray tubes the assembly containing one or more of these coils is called the yoke.

ELECTROMAGNETIC FIELD. It is commonly stated that a wire carrying an electric current is surrounded by a magnetic field whose lines of force are circles with the wire as their axis. This statement implies that the magnetic field is directly traceable to the

moving electricity in the wire. There is, however, another aspect of the matter. Each electric particle projects into space a field of electric force, and as the particles move along the wire the lines of force move with them. According to the theory of Maxwell, it is the motion of these lines of electric force that sets up the magnetic field transverse to them. More generally, a variable electric field is always accompanied by a magnetic field; and conversely, a variable magnetic field is accompanied by an electric field. The joint interplay of electric and magnetic forces here described is what is called an electromagnetic field, and is considered as having its own objective existence in space apart from any electric charges or magnets with which it may be associated. An essential feature of the theory is that this process, whatever it is, represents a flow of energy at right angles to both electric and magnetic components when the fields vary with time. The flux density of this energy (corresponding to the intensity of radiation) is represented by what is known as the **Poynting vector**. Electromagnetic radiation is, on this theory, the propagation of electric and magnetic stresses through space with the speed of light, somewhat as the much slower waves of elastic stress are propagated through steel. The conditions in an electromagnetic field are expressed mathematically by the well-known **Maxwell equations**. When an electric charge is set into motion, it builds about itself an electromagnetic field, and this implies a distribution of energy throughout space. The density of this energy at any point of the field is proportional to the product of the electric and magnetic vector components and the sine of the angle between the (vector product). The total field energy can be obtained by suitable integration, and is greater than that of the purely electric field of a stationary charge. The Maxwell theory treats this excess as kinetic energy, thus endowing the moving charge with an "electromagnetic mass" and an "electromagnetic momentum" inherent in its electrical character.

ELECTROMAGNETIC RADIATION. The entire range of radiations propagated by electric and magnetic fields and including gamma rays, x-rays, ultra-violet rays, light rays, infrared rays, heat rays and radio rays. These radiations extend continuously from those of the shortest wavelength (gamma rays) to the

longest radio waves; all travel with the speed of light.

ELECTROMAGNETIC WAVES. Waves which exhibit the properties of both electric fields and magnetic fields, and which extend in wavelength from the shortest **gamma rays** to the longest radio waves, including **x-rays**, light and heat waves in a continuous system. They are represented by vectors aligned in the directions in which the components are vibrating. The magnetic field is represented by H-vectors and the electric field is represented by E-vectors. The two fields are so oriented as to be at right angles to the direction or path of propagation and to each other. A wave is vertically polarized when the electric field is vertical. Electromagnetic waves may also be circularly or elliptically polarized, in which instances the fields are caused to rotate in either a circular or elliptical pattern. Elliptically polarized waves have the component of the electric vector, in a plane normal to the direction of propagation, describing an ellipse. They are transverse waves in which the displacement vector at any point rotates about the point, and has a magnitude which varies as the radius vector of an ellipse. An elliptically-polarized wave is equivalent to two superimposed plane-polarized waves of simple sinusoidal form in which the displacements lie in perpendicular planes and are in quadrature. Circularly polarized waves are elliptically-polarized waves in which the displacement at any points rotates about those points with constant angular velocity and has a constant magnitude. A linearly polarized wave is a transverse electromagnetic wave whose electric field vector lies along a fixed line. A plane polarized wave is one whose electric field vector lines lie in some fixed plane which also contains the direction of propagation. (Vertical and horizontal polarizations are both forms of plane polarization.) Φ -polarization occurs when the wave E-vector is tangential to the lines of latitude of a spherical frame of reference. When the polar axis is vertical and the origin is at the antenna, a vertical dipole will radiate only Θ -polarization and a horizontal loop will radiate only Φ -polarized waves. Θ -polarization occurs when the E-vector is tangential to the meridian lines of a given spherical frame of reference.

Polarization does not have significant effect

on transmitted waves until reflection or refraction occurs. Then reinforcement or cancellation may occur, and the choice of polarization may become important. In the use of polarized waves in radar systems, horizontal polarization is better when maximum range is a consideration since reflection from the ionosphere is facilitated (as well as from the earth). If gapless coverage or continuity of information is desired the vertical polarization is preferable. For radar it is better (generally) to use a vertical polarization for better reflectivity from the target.

Polarization becomes important when radars are attempting to track an extremely fast missile over long distances, especially ballistic missiles which present a small reflecting surface, since they turn downrange at high altitude and present only their exhaust nozzle toward the uprange launching area. In such cases it is necessary to make use of a beacon, and the polarization of this beacon is of some significance. A ballistic missile takes off in a vertical position and gradually programs over during its flight, until at **apogee** it is horizontal. Later during terminal flight it is reversed from its take-off attitude, i.e., heading straight downward.

Polarization is also of concern in equipment which tracks by means of continuous wave radiation, such as **DOVAP**. The signal from the DOVAP transponder is normally vertically polarized for continuity. Any metallic conductor between the missile and the receiving antenna on the ground can catch the missile signals and turn them in polarization, then reflect them into the ground antenna. This is especially true of metal guy wires. The result is a gap in the DOVAP record, which is tantamount to a loss of data.

ELECTROMETER. An instrument for measuring electric charge, usually by mechanical forces exerted on a charged electrode in an electric field.

ELECTROMOTIVE FORCE (EMF). The electric potential difference between the terminals of any device which is used or may be used as a source of electrical energy, i.e., to supply an electric current. More strictly, the limiting value of that potential difference which is found as the current flowing from the source approaches zero. To avoid ambiguity, the strict sense of the term is often indicated

by the use of the qualifying term "open circuit" or "no load."

The open circuit electromotive force of a cell is identical with its reversible potential difference; that of a rotating electrical machine is the potential difference existing across its terminals when the machine is neither receiving nor delivering electric power, i.e., is at the transition point between being a generator and being a motor. When a potential source of electrical energy, such as a **capacitor**, an **inductor**, or a rotating machine, is receiving energy from the external circuit, it is said to develop a counter-electromotive force. (See also **Kirchhoff laws**.)

ELECTROMOTIVE FORCE, AVERAGE.

For an alternating voltage (with no d-c component) the average value is zero. The term is often misused to mean the average absolute emf:

$$\frac{1}{T} \int_0^T |\varepsilon| dt.$$

For a sine wave, this is $2/\pi$ times the peak value.

ELECTROMOTIVE FORCE, MOTIONAL.

The electromotive force induced in a circuit by virtue of motion of the conductor across a magnetic field:

$$\varepsilon = \int \mathbf{v} \times \mathbf{B} \cdot d\mathbf{l},$$

where \mathbf{v} is the velocity of the conductor, \mathbf{B} is the magnetic flux density, and the integral extends over the length of the conductor, $d\mathbf{l}$ being an element of length.

ELECTRON. An elementary particle of rest mass $m_e = 9.107 \times 10^{-28}$ g and charge of 4.802×10^{-10} statcoulomb, and a spin of one-half unit, i.e., of $\hbar/2 = h/4\pi$. Its charge may be positive or negative, although the term electron is commonly used for the negative particle, which is also called the negatron. The positive electron is called the **positron**.

ELECTRON BEAM. A stream of electrons moving with about the same velocity and in the same direction, so as to form a beam.

ELECTRON, FREE. (1) An electron which is not restrained to remain in the immediate neighborhood of a nucleus or an atom. (2) The term free electron is also applied to any

electron in the outer electronic shell of an atom, when that electron is not shared by another atom, and especially when that electron is free to be so shared (to form a covalent bond).

ELECTRON GUN. An electrode structure which produces and may control, focus, and deflect an **electron beam**.

ELECTRON IMAGE TUBE. A **cathode-ray tube** used to increase the brightness or size of an image or to produce a visible image from invisible radiation such as infrared. A large, light-sensitive, cold cathode serves as the focal plane for the optical image. The resulting emission from the cathode is accelerated through an appropriate lens system before striking a fluorescent screen, where it produces an enlarged and brightened reproduction of the original image. This device has been employed in electron microscopes and telescopes, infrared microscopes and telescopes, and fluoroscope intensifiers.

ELECTRON MULTIPLICATION. On bombarding certain surfaces by electrons it may happen that each impinging electron expels several electrons from the struck surface. If these electrons are caught in an electric field and driven against another similar surface, each of them may again give rise to several electrons. After several such stages of multiplication, an appreciable **pulse** may be obtained in this manner, starting with a single electron as β -radiation, or produced photoelectrically by γ -radiation. Quantitatively, the electron multiplication of a device such as a photomultiplier is the ratio of the number of electrons reaching the anode to the number emitted at the cathode.

ELECTRON MULTIPLIER. A device for amplifying by a process of **electron multiplication**.

ELECTRON-MULTIPLIER PHOTOTUBE. A vacuum-type phototube that employs secondary emission to amplify the electron stream emitted from the illuminated photocathode. The electron stream impinges in turn on each of a series of reflecting electrodes called dynodes, at each of which secondary emission adds electrons to the stream. In one tube, an amplification of approximately 2,000,000 times is obtained with nine dynodes. Also termed photoelectric electron-multiplier tube and multiplier-phototube.

ELECTRON-MULTIPLIER TUBE. A tube employing **electron multiplication**, usually a photoelectric device. (See preceding entry.)

ELECTRON TUBE. Any completely evacuated or gas-filled tube used to control the flow of electrons in a circuit. Vacuum tubes, phototubes, mercury vapor rectifier tubes and cathode ray tubes are all electron tubes.

ELECTRON TUBE CIRCUITS. Electron tube circuits, that is, connections of resistors, inductors, capacitors, sources of power, and **electron tubes** assume a wide variety of forms. One convenient method of classifying electron tube circuits employs the amplitude of input signal as a basis. Reference to certain fundamental properties of electron tubes is desirable before describing the circuit classifications. For definiteness, the **triode** vacuum tube will be used as an example. If the **grid to cathode** voltage of such a tube is not allowed to become negative, the quantities associated with the device which are of principal interest in describing its behavior are the plate to cathode voltage drop, the plate current, and the grid to cathode voltage drop. The relations among these three variables are usually shown by a graph of two of the three quantities with the third assigned convenient (constant) values. The most common representation is the plate characteristic, a graph of the plate current—plate voltage relationship for various grid to cathode voltages. The intersections of the plate characteristics and the **load line** (the locus of all combinations of the plate voltage and current permitted by the constraints imposed by the elements external to the tube) establish a relation between grid voltage and plate current known as the transfer characteristic. A typical transfer characteristic is shown in Figure 1.

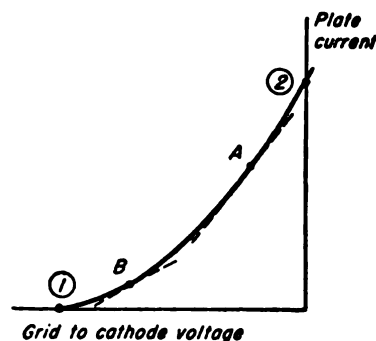


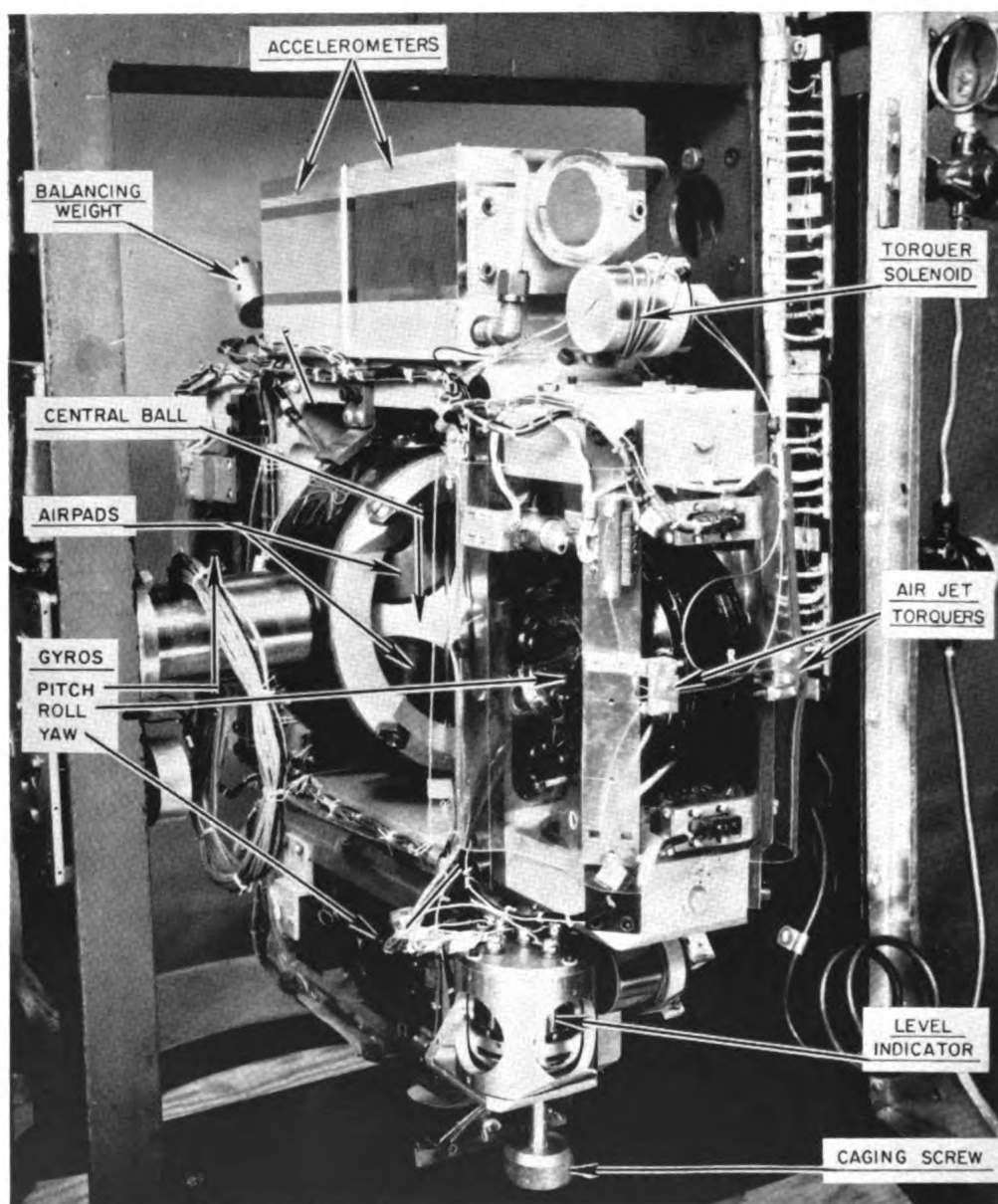
Fig. 1. Typical transfer characteristic for triode vacuum tubes.



The U.S. Army HAWK guided missile is fired from launcher during test held at the Army Blockhouse, White Sands Proving Grounds. August 27, 1957. (*U.S. Army Photograph*)



The U.S. Army HONEST JOHN rocket is fired from launcher during test held at the Army Blockhouse, White Sands Proving Grounds. August 26, 1957. (*U.S. Army Photograph*)



First successful tests of an inertial navigation stabilized platform in this country are stated to have been made by this instrument designed and developed in 1950 by Autonetics, a division of North American Aviation. Designated the XN-1, successful flight tests constituted a major step toward application of inertial guidance principals to long-range missiles. Instrument has three single-degree-of-freedom stabilizing gyroscopes to maintain spatial reference coordinate system in which accelerations are measured and position computed. On top are two accelerometers which sense vehicle accelerations in horizontal plane. Solenoid-operated air-jet torquers provide force that keeps platform in desired attitude at all times. (Photograph by Autonetics, a division of North American, Inc.)

Point (1) is commonly referred to as "cut off" for the tube since the plate current is reduced to zero. Point (2) is identified as the "zero bias" point. The difference in grid to cathode voltage between zero bias and cut off is often referred to as the "grid base" of the tube.

This characteristic tells at a glance the plate current to be expected for a given grid to cathode voltage. In practice a grid bias is chosen so that in conjunction with the assigned plate to cathode voltage an appropriate operating point is established about which changes in grid voltage and plate current will take place when an output signal is applied between grid and cathode. The points *A* and *B* in Figure 1 are typical operating points. The choice of operating point is an important

whether the tubes operate in a linear fashion corresponding to small signal inputs or whether the input signals are large enough to cause excursions over such a large portion of the transfer characteristic that the tangent to curve at the operating point is not a good approximation to the tube behavior over the entire amplitude range of the input signal. There are thus two principal categories of vacuum tube operation, namely, linear or small signal behavior and nonlinear or large signal action. Large signal operation is usually analyzed by the use of graphical constructions utilizing plate characteristics, whereas small signal operation is treated by equivalent circuits by means of which changes in plate current and plate voltage from the quiescent values may be computed.

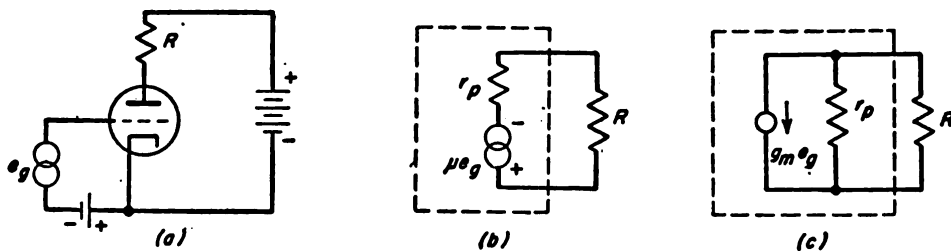


Fig. 2. (a) Triode amplifier circuit; (b) Constant voltage generator equivalent circuit; (c) Constant current generator equivalent circuit.

consideration in the operation of a tube as an amplifier (see **Amplifier**). It is seen from Figure 1 that, although the transfer characteristic is not linear, there are certain regions where the slope of the curve does not change appreciably over a fairly large increment of grid voltage. Depending on the location of the operating point, it is possible to choose an amplitude of input signal so that the change in plate current for this amplitude and all smaller values can be considered to be linearly related to the input signal within a prescribed small amount of error. Operation with such a combination of bias and input signal amplitude is called linear operation of the tube. It is clear from the figure that the range of input signal amplitude permitted to achieve a prescribed degree of linearity between grid voltage and plate current depends on the choice of operating point. Point *A* permits a larger value of input signal for a prescribed degree of linearity, for example, than does point *B*.

Vacuum tube circuits can be classified as to

Figure 2(a) shows a simple triode amplifier circuit. If the choice of the operating point and the signal level result in linear operation, the two equivalent circuits in Figures 2(b) and 2(c) may be used to compute the change in plate current and plate voltage which occur about the operating point as a result of the application of the signal. The parameters μ , g_m , and r_p are the amplification factor, mutual conductance and plate resistance of the tube, respectively. The generator [constant voltage in 2(b); constant current in 2(c)] and resistor shown in the dashed outline replace the tube between the plate and cathode terminals as far as changes in voltage and current in the circuit external to the tube are concerned. Corresponding equivalent circuits exist for **tetrode** and **pentode** operation. If the voltages applied to the extra electrodes of these tube types vary with the applied signal, provision must be made for these changes in the formulation of the equivalent circuits. If, on the other hand, the voltages applied remain constant with time (except for

the plate voltage), then the equivalent circuits assume the same form as shown in the boxes in Figures 2(b) and 2(c).

Nonlinearity in the tube characteristic can be accounted for by an extension of the simple equivalent circuit just presented. If additional voltage generators having strengths proportional to e_p^2 , e_p^3 , and higher powers of the varying grid to cathode voltage are introduced, it is found that the actual nonlinear tube characteristic can be approximated quite well. This scheme represents the expression by an electrical circuit of the mathematical principle of expanding the plate current in a Taylor series as a function of the grid voltage. The power series technique is useful in making calculations for tubes used for **detection** and **modulation** as well as in computations of amplitude **distortion**.

The references cited at the beginning of this section give many examples of electron tube circuits in which linear operation or slightly nonlinear operation is involved. In the two oscillator sections, however, circuits are presented in which the operating points for the tubes undergo large excursions over a complete operating cycle. It is common in the multivibrator circuit (see **Relaxation Oscillator**), for example, for a tube to have its grid voltage swing from the zero bias condition to far beyond cutoff. This behavior is found in many pulse-generating or pulse-shaping circuits. Several vacuum tube circuits of this form will be considered as examples.

A trigger or flip-flop circuit is one which has two conditions of stable equilibrium and which can be switched from one stable state to the other by some external influence such as the application of an input pulse. Figure 3 shows one the most common flip-flop circuits,

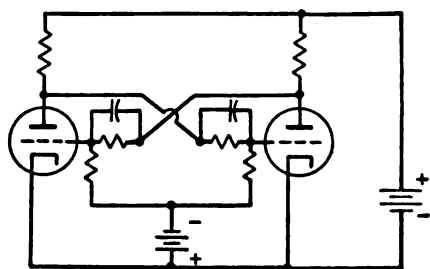


Fig. 3. Eccles-Jordan circuit.

the Eccles-Jordan circuit. Two triodes are used in a symmetrical circuit so arranged that one tube is at zero bias and the other is cut

off. A positive trigger pulse of sufficient amplitude applied to the grid of the tube cut off, or a negative pulse applied between grid and cathode of the conducting tube, causes a positive **feedback** action which results in a rapid change of state in each tube. The conducting tube is forced to the cut off state, while at the same time the tube previously cut off is forced into conduction near zero bias. This change of states is effected by the connection from the plate of one tube to the grid of the other. If a tube conducts plate current, the potential at the plate is reduced below the battery voltage by the voltage drop in the resistor connected from the plate to the battery. The grid voltage of the other tube is thus forced by voltage divider action to be below the potential previously attained when plate current was cut off in the first tube. By proper design of the voltage divider and the negative battery supply, the grid to cathode voltage can be made to swing from a slightly positive value (approximately zero bias) to a negative value sufficient to cut the tube off as a result of the variation of the plate voltage of the other tube as the latter changes from the cut off value to that at the full conduction condition. The capacitors shown are used to overcome the delay in switching from one state to another resulting from wiring capacitance and the grid to cathode **interelectrode capacitance**. Since it takes two input pulses to cause the circuit to revert to its original state, the circuit is frequently used as an electronic counter. In this application, several of the circuits are connected in cascade with one circuit furnishing the trigger for the succeeding one and being triggered from the preceding one in the tandem connection. Such a device is known as a scale of two counter. In a three circuit cascade connection, for example, eight input pulses are required to produce one output pulse.

Because of the d-c coupling employed in the circuit of Figure 3, there are two stable equilibrium states possible, i.e., the circuit can remain indefinitely in either of the two states. The multivibrator circuit described in the *relaxation oscillator* section, on the other hand, has no state in which it can remain indefinitely; it is forced to revert from one state to the other continually. It is sometimes called an **astable multivibrator**, whereas the trigger circuit just described is sometimes spoken of as a **bistable multivibrator**. Modification of

the circuit of Figure 3, by removing the provision for d-c coupling between one plate and the next grid, results in a circuit having only one stable state which is known as a monostable multivibrator. A typical circuit is shown in Figure 4. Assuming that the circuit

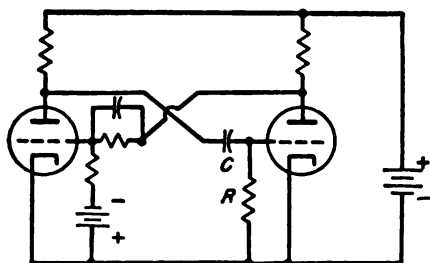


Fig. 4. Monostable multivibrator circuit.

has been at rest for some time, the right hand triode conducts at zero bias and the left hand tube is cut off. Application of a trigger pulse of suitable polarity and amplitude causes a rapid reversal of these conduction states. The left hand tube comes into full plate current conduction with the change in voltage produced across its load resistor being transmitted undiminished to the grid of the right hand tube. The full amount of the decrease in plate potential is experienced at the next grid inasmuch as the voltage across capacitor C cannot change instantaneously. The right hand tube is cut off by this change in voltage. As time progresses, however, the current flowing in the elements R and C , as capacitor C discharges, causes a voltage across R (negative from grid to cathode) which is no longer sufficient to keep the right hand tube cut off. Plate current therefore begins to flow, positive feedback develops, and the tubes once more exchange conducting and nonconducting roles. The state during which the left hand tube conducts is an unstable one. Its duration is controlled largely by the product RC , the voltage change developed across the load resistor of the left hand tube, and the cut off bias of the right hand tube.

Another pulse type circuit, which utilizes the transient voltage produced in a resistor-capacitor circuit, is the sweep circuit employed for deflecting the electron beam in a cathode ray tube (see **Cathode Ray Tube**). Figure 5(a) shows a simple circuit for generating a sweep voltage. The important voltage waveforms are illustrated in Figure 5(b). Prior to time t_1 , the triode conducts at zero bias, and

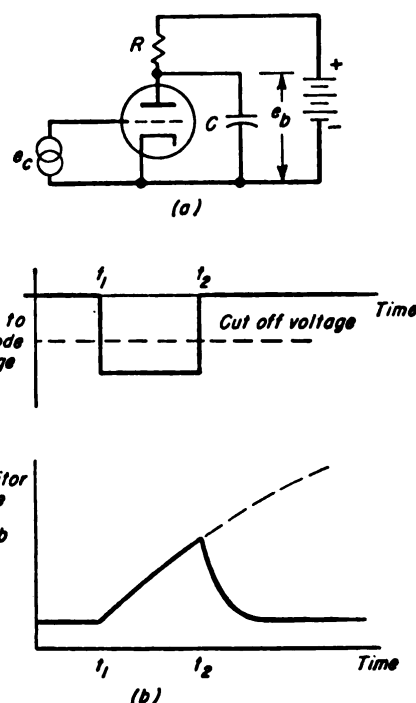


Fig. 5. (a) Typical sweep generator circuit; (b) Input and output voltage waveforms for sweep circuits.

the voltage across capacitor C is only a small fraction of the battery voltage because of the voltage drop in the large resistor R . At time t_1 the grid to cathode voltage is made negative enough to cut off the flow of plate current. This condition is maintained until time t_2 . During the interval of time that the tube is cut off, the capacitor C is charged from the battery through the resistor R . The voltage across the capacitor increases along the exponential curve associated with the transient in a resistor-capacitor circuit. Ultimately e_b would become equal to the battery voltage. The exponential rise is not permitted to continue after time t_2 , however, for when the tube is returned to zero bias at that time, the capacitor discharges through the tube and its voltage rapidly assumes the value which it had at the start of the charging process. Many refinements, including **feedback**, may be added to the circuit of Figure 5(a) to increase the degree of linearity of the voltage change between t_1 and t_2 .

The blocking oscillator circuit shown in Figure 6 is another circuit in which the grid to cathode voltage undergoes a wide variation in the execution of the operating cycle. There are several forms of blocking oscillator cir-

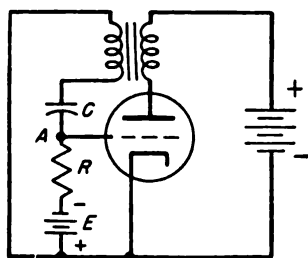


Fig. 6. Blocking oscillator.

cuits. The version illustrated requires an external stimulus (a positive trigger pulse applied at point A, for example) in order to initiate circuit action. The battery E keeps the tube cut off in the absence of an input signal, and thus the trigger pulse must be of sufficient magnitude to bring the tube into conduction and initiate the positive feedback action to which reference has been made earlier. As the plate current increases in response to the trigger signal, there is a voltage developed across both windings of the transformer. The windings are connected so that the increase in current in the plate winding causes the grid to cathode voltage to increase. This action causes the plate current to increase still more and the plate to cathode voltage to decrease. This regenerative action continues until the grid potential has reached such a high value accompanied by a simultaneous low value of plate voltage that, because of tube nonlinearities, the rate of change of plate current becomes zero and then actually reverses. The latter action starts a decrease of grid voltage which, because of the feedback action, is also cumulative and the tube is rapidly cut off. During the positive grid operation the flow of grid current charges the capacitor C so that, when the tube is suddenly cut off and there is no longer a low resistance path from grid to cathode, the capacitor must discharge through resistor R and the grid winding of the transformer. Until the discharge process is completed, the grid to cathode voltage is more negative than the battery voltage E because of the voltage drop in resistor R . The length of time that the tube conducts, and thus the width of the plate current pulse, is determined largely by the characteristics of the transformer and the properties of the tube in the positive grid voltage region. The output signal from the circuit may be taken from the plate or a third winding may be used on the transformer to

provide either a positive or negative output pulse. The principal use of the blocking oscillator is to furnish extremely narrow pulses. Typical applications occur in radar equipment, television receivers and transmitters, and cathode ray measuring apparatus. If the voltage E is set to zero, the blocking oscillator shown becomes self triggering inasmuch as it is possible for the positive feedback action to commence at some value of grid to cathode voltage between cut off and zero bias. When the circuit triggers itself, the rate at which pulses are generated is determined principally by the value of grid to cathode voltage needed to start regenerative action and by the product of the element values of resistor R and capacitor C . The discharge process involving R and C controls the time interval that the tube is cut off in exactly the same fashion as in the monostable multivibrator discussed earlier.

The circuits described give some indication of the ways in which tubes are used for large signal applications. Combined with the references to the small signal circuits, the illustrations provide a broad view of the great variety of ways in which electron tubes may be employed.

ELECTRON VOLT. The energy received by an electron in being accelerated by a potential difference of one volt.

ELECTRONIC COUNTERMEASURES (ECM). Countermeasures.

ELECTRONIC DECEPTION. Deception, electronic.

ELECTRONIC EQUIPMENT, A-N SYSTEM OF NOMENCLATURE. A-N System of Nomenclature for Electronic Equipment.

ELECTRONIC MISSILE ACQUISITION (EMA). A measuring system for providing angular data (azimuth and elevation angle) by a phase comparison of RF signals received from a missile.

ELECTRONIC SKY SCREEN EQUIPMENT. ELSSE Cotar.

ELECTRONIC SWITCH. An electron tube (see tube, electron) device for alternately switching between two input signals. It consists of two amplifier channels, each fed by one of the inputs, arranged so they are alter-

nately biased to cutoff (i.e., become inoperative) and feeding a common output.

ELECTRONIC TUNING. (1) In reflex **klystrons** the alteration of the frequency of oscillation by changing the repeller voltage. (2) Changing the frequency of operation of a transmitter or receiver by changing a control voltage.

ELECTRONICS WARFARE. The use of electronics to prosecute or support combat operations. For example: guided missile control, communications, or target detection.

ELECTROPLATING. The coating of an object with a thin layer of some metal through electrolytic deposition.

ELECTROSCOPE. An instrument for detecting small charges of electricity, or for measuring small voltages, or sometimes, indirectly, very small electric currents, by means of the mechanical forces exerted between electrically-charged bodies. One of the earliest sensitive electroscopes consists of two narrow strips of gold-leaf hanging together in a glass jar. Upon being charged, they stand apart on account of their mutual repulsion. One leaf may be replaced by a stiff strip of brass, so that only the remaining leaf can move. The Wilson electroscope has a single gold-leaf which, on being charged, is attracted by a grounded metal plate tipped at such an angle as to give maximum sensitivity.

ELECTROSTATIC. Pertaining to stationary electric charges as on the plates of a charged condenser.

ELECTROSTATIC DEFLECTION. The deflection of an **electron beam** as a result of its passing through an electrostatic field which has a component perpendicular to the path of the beam.

ELECTROSTATIC LENS. An arrangement of electrodes so disposed that the resulting electric fields produce a focusing effect on a beam of charged particles.

ELEMENT. (1) A part of a physical system which defines a distinct activity in its part of the system. For example, an element in an electrical system may be a device such as an inductor, resistor, capacitor, generator,

line, electron tube or semiconductor with terminals at which it may be directly connected to similar electrical devices. (2) An integral part of a device (for example, a part of an electron tube or semiconductor) which contributes to its operation. (3) A parameter in a physical system which defines a distinct activity in the system or some part of the system. For example, such parameters in electrical circuits are resistance, inductance and capacitance; in a mechanical rectilinear system they are mechanical rectilinear resistance, mass and compliance; in a mechanical rotational system they are mechanical rotational resistance, moment of inertia and rotational compliance; in an acoustical system they are acoustical resistance, inertance and acoustical capacitance. (4) An aggregation of atoms of one kind having the same atomic number (and hence the same chemical properties); or an aggregation of atoms all having the same atomic number, mass number and nuclear stability classification. (See table on Page 224.) (5) In mathematics a quality defined by two symbols designating a row and column in an array. (6) In military science, a distinctive part of an organization.

ELEVATION. (1) The vertical distance from a datum, usually mean sea-level, to a point or object on or above the earth's surface. (2) In gunnery, the angle to which the gun tube is elevated measured vertically above the horizontal at the gun pintle.

ELEVATION QUADRANT. A measure of launcher elevation position. The measurement is made with a gunner's quadrant.

ELEVATOR. A control surface moved to cause an aircraft or missile to move about its lateral (usually pitch) axis.

ELEVONS. Control surfaces having the functions of both **elevators** and **ailerons**, i.e., capable of inducing motion in pitch and/or roll. Elevons work as elevators when moved in the same sense, and as ailerons when moved in the opposite sense. They are normally mounted on wings in the same position as ailerons.

ELLIPSE. A conic section obtained by a cutting plane parallel to no element of a right circular conical surface. It is the locus of a point which moves so that the sum of its dis-

ATOMIC WEIGHTS OF THE ELEMENTS

	Symbol	Atomic Number	Atomic Weight *		Symbol	Atomic Number	Atomic Weight *
Actinium	Ac	89	227	Neodymium	Nd	60	144.27
Aluminium	Al	13	26.98	Neon	Ne	10	20.183
Americium	Am	95	[243]	Neptunium	Np	93	[237]
Antimony	Sb	51	121.76	Nickel	Ni	28	58.69
Argon	A	18	39.944	Niobium			
Arsenic	As	33	74.91	(Columbium)	Nb	41	92.91
Astatine	At	85	[210]	Nitrogen	N	7	14.008
Barium	Ba	56	137.36	Osmium	Os	76	190.2
Berkelium	Bk	97	[245]	Oxygen	O	8	16.0000
Beryllium	Be	4	9.013	Palladium	Pd	46	106.7
Bismuth	Bi	83	209.00	Phosphorus	P	15	30.975
Boron	B	5	10.82	Platinum	Pt	78	195.23
Bromine	Br	35	79.916	Plutonium	Pu	94	[242]
Cadmium	Cd	48	112.41	Polonium	Po	84	210
Calcium	Ca	20	40.08	Potassium	K	19	39.100
Californium	Cf	98	[246]	Praseodymium	Pr	59	140.92
Carbon	C	6	12.010	Promethium	Pm	61	[145]
Cerium	Ce	58	140.13	Protactinium	Pa	91	231
Cesium	Cs	55	132.91	Radium	Ra	88	226.05
Chlorine	Cl	17	35.457	Radon	Rn	86	222
Chromium	Cr	24	52.01	Rhenium	Re	75	186.31
Cobalt	Co	27	58.94	Rhodium	Rh	45	102.91
Copper	Cu	29	63.54	Rubidium	Rb	37	85.48
Curium	Cm	96	[243]	Ruthenium	Ru	44	101.7
Dysprosium	Dy	66	162.46	Samarium	Sm	62	150.43
Erbium	Er	68	167.2	Scandium	Sc	21	44.96
Europium	Eu	63	152.0	Selenium	Se	34	78.96
Fluorine	F	9	19.00	Silicon	Si	14	28.09
Francium	Fr	87	[223]	Silver	Ag	47	107.880
Gadolinium	Gd	64	156.9	Sodium	Na	11	22.997
Gallium	Ga	31	69.72	Strontium	Sr	38	87.63
Germanium	Ge	32	72.60	Sulfur	S	16	32.066
Gold	Au	79	197.2	Tantalum	Ta	73	180.88
Hafnium	Hf	72	178.6	Technetium	Tc	43	[99]
Helium	He	2	4.003	Tellurium	Te	52	127.61
Holmium	Ho	67	164.94	Terbium	Tb	65	159.2
Hydrogen	H	1	1.0080	Thallium	Tl	81	204.39
Indium	In	49	114.76	Thorium	Th	90	232.12
Iodine	I	53	126.91	Thulium	Tm	69	169.4
Iridium	Ir	77	193.1	Tin	Sn	50	118.70
Iron	Fe	26	55.85	Titanium	Ti	22	47.90
Krypton	Kr	36	83.80	Tungsten			
Lanthanum	La	57	138.92	(Wolfram)	W	74	183.92
Lead	Pb	82	207.21	Uranium	U	92	238.07
Lithium	Li	3	6.940	Vanadium	V	23	50.95
Lutetium	Lu	71	174.99	Xenon	Xe	54	131.3
Magnesium	Mg	12	24.32	Ytterbium	Yb	70	173.04
Manganese	Mn	25	54.93	Yttrium	Y	39	88.92
Mercury	Hg	80	200.61	Zinc	Zn	30	65.38
Molybdenum	Mo	42	95.95	Zirconium	Zr	40	91.22

* A value given in brackets denotes the mass number of the most stable known isotope.

† The Atomic Weights Commission recommends that a range of ± 0.003 be attached to the official value of 32.066.

Elements 99-102 (einsteinium, fermium, mendelevium and nobelium) are not included.

tances from two foci is a constant. Its eccentricity is less than unity. The standard equation may be taken as

$$x^2/a^2 + y^2/b^2 = 1.$$

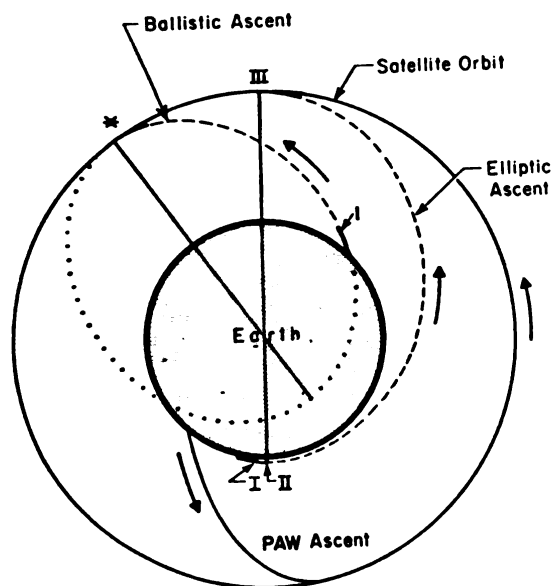
The curve is a central conic for it is symmetric about both the X- and Y-axes. When placed in this standard position, the center of the ellipse is the coordinate origin, the major axis of length $2a$ is along the X-axes, and the

minor axis of length $2b$ is along the Y-axes. The distance from the center to either focus is $\sqrt{a^2 - b^2}$; the eccentricity e is given by $ae = \sqrt{a^2 - b^2}$; the length of the latus rectum is $2b^2/a$; the equations for the directrices are $x = \pm a/e$. The distance from any point on the ellipse to a focus is a focal radius, and sum of two focal radii equals $2a$. If the semi-major axis equals the semi-minor axis, the ellipse degenerates into a circle.

The ellipse is the form of practically all space flight trajectories.

ELLIPSE, HOHMANN TRANSFER. Hohmann transfer ellipse.

ELLIPTIC ASCENT. The ascent of a space vehicle from earth to its orbit as shown in the path designated by I, II and III in the figure. For the elliptic ascent, Stations I and II indicate the points at which local circular velocity



Ascent trajectories.

and perigee velocity of the transfer ellipse, respectively, are attained. Station III indicates the apogee transfer into the target orbit. (See also ballistic ascent.)

ELLIPTIC VELOCITY. The velocity of a body whose orbit is an ellipse.

ELSSSE COTAR (ELectronic Sky Screen Equipment). A passive range instrumentation system using on the ground the Sky Screen System to receive transmitted data

from any airborne transponder which may be used for other purposes: e.g., FM/FM telemetering transmits at a satisfactory frequency for this system. It is usually employed for range safety.

EMA. Electronic Missile Acquisition.

EMAGRAM. A meteorological chart of temperature plotted against the logarithm of pressure.

EMERGENCY POWER SUPPLY (EPS). A primary battery that supplies electrical power for certain range safety components during missile flight.

EMISSIVITY. The ratio of the radiation emitted by a surface to the radiation emitted by a complete radiator (black body) at the same temperature and under similar conditions. The emissivity may be expressed for the total radiation of all wavelengths (total emissivity), for visible light (luminous emissivity) as a function of wavelength (spectral emissivity) or for some very narrow band of wavelengths (monochromatic emissivity). Excepting for luminescent materials, the emissivity can never be greater than unity.

EML. Equipment Modification List.

EMPENNAGE. (*Obs.*) A word of French origin used to denote the tail unit of an airplane. It includes both the vertical and horizontal stabilizers and their associated control surfaces.

ENCAPSULATION. The technique of enclosing components (usually electrical) within a body of protective material (such as resin). The purpose of encapsulation is to give mechanical strength, as well as to provide insulating properties around a component which is likely to be subjected to vibration or altitude effects.

ENCODER (Analog-Digital). A device for converting information available in analog form into a form suitable for processing by a digital computer. (Decoders are used to convert digital data to analog form.)

END BURNER. Propellant, restricted.

END BURNING GRAIN. Restricted burning grain; propellant, restricted.

END INSTRUMENT. (Pickup) In missile telemetry system, the pick-up device at the missile end of the **telemetry** link which serves to detect and measure the physical quantity under investigation. It is the first device in the telemetry link. It may be a pressure-sensitive device (**transducer**) used to convert fuel pressure to voltage; it may be a potentiometer which yields a voltage proportional to the physical rotation or translation of a missile part to which it is attached; or it may be any of a number of other devices such as strain gauges, **accelerometers**, **gyroscopes**, etc. End instruments are designed for the quantity to be measured, and the conditions at the place of measurement. They are used, most commonly, as in the examples cited, to transform a physical quantity into an electrical voltage, which is applied to the telemetry system to modulate the signal transmitted. These end instruments are usually non-linear devices, and so they are the major source of nonlinearities in the telemetry data received. Data reduction processes must linearize their output from preflight ground calibrations, and the error in predicting this variation during flight is a source of **data reduction error**.

END ITEM. In U.S. Air Force terminology, any combination of parts, assemblies, accessories, and attachments which when integrated form an equipment that accomplishes a complete function.

END ORGAN. **Telemetry pickup; organ, end instrument.**

END PRODUCT. (1) Any material, part, sub-assembly, or assembly in its final completed state, as governed by specifications, drawing, provisions of contract or order, or other requirements. (2) The final product of a reaction or process. In **radioactive series**, the stable nuclide constituting the last member of the series.

END PRODUCT DRAWING. A drawing showing an **end product**. An end product drawing, covering the detail of an individual part, should include all dimensions, tolerances, notes and other data necessary to describe fully the size, shape, and other characteristics of the part as it appears in its completed state, but should not include references to intermediate steps in the production proc-

ess, such as roughing operations with dimensions and limits pertaining thereto, or to specific manufacturing methods.

END-FIRE ARRAY. **Antenna array, end-fire.**

ENDOTHERMIC. Characterized by an absorption of heat or other energy.

ENDURANCE LIMIT. A limiting stress, below which a material (usually a metal or alloy) will withstand without fracture an indefinitely large number of cycles of stress. If the term is used without qualification, the cycles of stress are usually such as to produce complete reversal of flexural stress. Above this limit failure occurs by the generation and growth of cracks until fracture results in the remaining section.

The effect of repeated reversal of stresses is to cold work the steel and the results produced are the same. From tests that have been made the endurance limit for steel appears to be obtained at 10^7 cycles and is approximately $\frac{1}{2}$ the tensile strength. In plotting the results of these tests the load per square inch and the number of cycles are used as co-ordinates and are called **S-N curves**. In actual practice, allowances should be made for stress raisers such as notches, unequal stress applications, etc., and design varied accordingly.

ENERGY. The ability to do work. Thus, a capacitance of magnitude C , carrying a charge Q , possesses electrical energy in the amount $Q^2/2C$, and can do this much work in the process of being discharged. In this instance, the energy is considered to reside in the electric field between the plates of the capacitor. In other cases, e.g., that of kinetic energy (see **energy, kinetic**) the energy is considered to reside in the body itself. The mechanical or electrical energy of a system is always measured as the maximum amount of work that the system can do in coming to static equilibrium.

When other forms of energy than electrical or mechanical are concerned (e.g., thermal or chemical energies) the elementary definition is not completely satisfactory, since the amount of work that can be done depends on the surroundings as well as on the state of the body. In such cases, the definition given above is that of the **free energy**, and

the total energy is better defined as the maximum amount of work that the system can do in coming to static equilibrium at the absolute zero of temperature. Even this definition breaks down, however, if the system possesses **zero point energy**.

In special relativity, energy and mass are equivalent being connected by the Einstein equation $E = mc^2$ where c is the speed of light. Hence, when relativistic mechanics must be applied, e.g., when speeds comparable to c are involved, the energy of a system includes the rest energy m_0c^2 of all the bodies in the system. Here m_0 is the mass of a body at rest with respect to the other bodies of the system and to the observer.

Energy is particularly important because it is a conserved quantity, which can be neither created nor destroyed. It may, however, be exchanged among various bodies or may be converted from one form to another, or interconverted with mass as in the Einstein equation above. (See also **work; conservation of energy, law of**.)

ENERGY CONVERSION EFFICIENCY.

The efficiency with which a nozzle converts the energy of the working substance into kinetic energy, expressed as the ratio of the kinetic energy of the jet leaving the nozzle to the kinetic energy of a hypothetical ideal jet leaving an ideal nozzle using the same working substance at the same initial state and under the same conditions of velocity and expansion.

ENERGY DISSIPATION. (1) The large quantity of energy accumulated during flight into space must be dissipated during the descent. As long as considerably more powerful propulsion systems are not available, slowdown by means of reverse thrust is not yet feasible, though work on **retro-rockets** is in progress. The only other possibility is dissipation to the atmosphere. One very effective means of energy dissipation is the hypersonic glider configuration. (Here the word hypersonic indicates a flight Mach number exceeding 5.) In contrast to a long-range glide vehicle for which high lift at low drag is essential, the returning orbital glider should produce high lift and high drag. The drag is required for braking the speed. High lift is important in order to employ the braking process at the highest possible altitudes, thereby reducing the intensity of aerodynamic heating by mini-

mizing the pressure in the boundary layer behind a shock wave of given strength. This does not reduce the temperature in the boundary layer (except by a small amount, if one considers dissociated boundary layer molecules), but it reduces the transfer of heat into the wall, because the transfer coefficient is proportional to the square root of the pressure. By reason of the simultaneous need for high drag and high lift, the vehicle drag should preferably consist of drag incident to lift rather than bluntness. Particularly significant for the descent phase are the cockpit cooling requirements to protect personnel and equipment. The thermal stress problem is considerably more serious than for the booster stages during ascent, because of more intense heating of the large flat areas needed to obtain the low wing-loading. (2) The maintenance of tolerable temperature within a flight vehicle or its equipments often requires the dissipation of heat energy; this can be accomplished by radiation to space and/or convection to the atmosphere, depending upon the flight environment.

ENERGY, INTERNAL. The energy ascribed to a given state of a system, which is determined only by the state itself (and is thus a scalar quantity) and is not accounted for by the kinetic energy of bulk motion or potential energy in external force fields. By thermodynamics, the change in the internal energy when the system goes adiabatically from one state to another is equal to the external work performed in bringing about the change. On a molecular scale, the internal energy is the sum of the kinetic energy of the thermal motion of the molecules and the sum of their potential energies in each other's fields of force. By the first law of thermodynamics, the change of internal energy in any process is equal to the difference of the heat gained and the external work done. In this book the symbol U is used for internal energy; however, E is also in general use.

ENERGY, KINETIC. The most obvious way in which a body can manifest energy is to be in motion. Experience impels us to get out of the way when we see a rapidly moving, massive object approaching. We know that the more massive it is, and the faster it moves, the more work (and the more damage) it will do when it strikes. A simple course of reason-

ing based on Newton's laws of motion leads to the formula $E = \frac{1}{2}mv^2$ for the kinetic energy (in absolute units) of a mass m moving with a speed v . Thus a stone of mass 100 grams moving with a speed of 1000 cm per sec has $\frac{1}{2} \times 100 \text{ g} \times 1000^2 \text{ cm}^2/\text{sec}^2 = 50,000,000 \text{ g cm}^2/\text{sec}^2$ (or ergs) of kinetic energy. When the moving body is brought to rest by a force of average value f , and continues to move a distance, d , after this force is applied, it does an amount of work, fd , equal to its kinetic energy $\frac{1}{2}mv^2$. If d is very small, f must be large. Thus, if the stone in the above example were stopped in a space of 0.01 cm (as in striking a hard obstacle), we should have $0.01 \text{ cm} \times f = 50,000,000 \text{ g cm}^2/\text{sec}^2$, or $f = 5,000,000,000 \text{ g cm/sec}^2$ (or dynes), which is equivalent to 5100 kilograms or more than 5.6 tons.

The kinetic energy of a body rotating with angular speed ω (radians per sec) about an axis for which its moment of inertia is I , is $E = \frac{1}{2}I\omega^2$; or $2\pi^2In^2$, where n is the number of rotations per sec. The theory of relativity gives slightly higher values for the kinetic energy, but the differences are negligible except for very great speeds.

ENERGY OF ACTUATION. The energy required to break up a complex fuel or oxidizer compound so that its elements can undergo combustion.

ENERGY, POTENTIAL. The negative of the work done by the forces of a conservative system when the particles of the system move from one configuration to another is the potential energy of the second configuration relative to the first configuration. This quantity is independent of the path followed by the particles in changing their configuration and is a function of the initial and final positions only.

An equivalent definition states that the potential energy is that particular function of the coordinates $V(x,y,z)$ whose negative gradient exists and is equal to the force, i.e.,

$$\mathbf{F} = -\nabla V.$$

The existence of V implies a conservative force field.

If the force between two particles separated by a distance r is given by $F = K/r^2$, the mutual potential energy of the particles when separated by a distance r is

$$-\int_{r_0}^r \frac{K}{r^2} dr,$$

where r_0 is the distance of separation in the initial or standard configuration. For convenience, r_0 is often taken as infinity, in which case the potential energy at infinity is considered to be zero and the potential energy of the final configuration is then K/r . Actually the numerical value of the potential energy is arbitrary because the initial configuration can be chosen arbitrarily. Any constant can be added to the potential energy function and the condition $\mathbf{F} = -\nabla V$ will still be satisfied.

A particle on the surface of the earth is acted upon by a force of mg dynes where m is the mass in grams and g is the acceleration of gravity in cm per sec² at the particular point. If the particle is raised a height h centimeters above the surface of the earth, where h is small in comparison with the radius of the earth, the potential energy of the particle with respect to the earth's surface becomes mgh ergs. For example, a 10 gram mass at a distance of 100 cm above the ground has a potential energy of about $(10)(100)(980) = 980,000$ ergs. If the mass were allowed to fall to the ground in a vacuum, the potential energy would be converted completely into 980,000 ergs of kinetic energy, thus exemplifying the conservation of energy.

ENERGY, RADIANT. Energy which is transferred by electromagnetic waves without a corresponding transfer of matter.

ENGINE, BY-PASS. By-pass engine.

ENGINE EFFICIENCY. The ratio of the amount of work obtained from the engine to the amount of heat put in, the two quantities being measured in the same units.

ENGINE, ROCKET. Rocket engine.

ENGINEERING SEQUENTIAL PHOTOGRAPHY. The continuous recording of an event by means of photographs taken in time sequence. Still or motion picture photography may be used.

ENGINEERING SURVEILLANCE PHOTOGRAPHY. A type of coverage by either still or motion picture photography, used to give a record of events occurring during the development testing of a device. Surveil-

lance photography includes both documentary and engineering sequential photography. It is not necessary that a time-ordered sequence of events be maintained, but the time correlation and/or the timing itself may depend upon the nature of the event recorded.

ENGINEERING SYSTEM OF AERODYNAMIC UNITS. A system of units for expressing lift and drag coefficients of an airframe, derived from one square foot of area of the surface traveling at a speed of one mile an hour at a given angle of attack. The system is easier to use than the absolute system, but has the disadvantage that the coefficients are not dimensionless, but change with the density of the air and with the lineal dimensions. The units are expressed as lift in pounds, area in square feet, velocity in miles per hour.

ENTHALPY. A thermodynamic concept defined by the equation $H = E + PV$ where H is the enthalpy, E is the energy, P , the pressure, and V , the volume of a system. At constant pressure the change in enthalpy measures the quantity of heat exchanged by the system with its surroundings.

ENTROPY. (1) In the mathematical treatment of thermodynamic processes there occurs very often a quantity, now relating energy to absolute temperature, now associated with the probability of a given distribution of momentum among molecules, and again expressing the degree in which the energy of a system has ceased to be available. Its mathematical form suggests that these are all aspects of a single physical magnitude. Application of the second law of thermodynamics leads to the conclusion that if any physical system is left to itself and allowed to distribute its energy in its own way, it always does so in a manner such that this quantity, called "entropy," increases; while at the same time the available energy of the system diminishes. This law applies to the universe as a whole, hence the proposition that the total entropy increases as time goes on. An interesting conclusion as to entropy in the vicinity of absolute zero is expressed by the Nernst heat theorem; viz., that all physical and chemical changes in this region take place at constant entropy. Any process during which there is no change of entropy is said to be "isentropic." This is true, for

example, of an adiabatic process in which there is no dissipation of energy, i.e., one which is also a reversible process. In thermodynamic discussions entropy is commonly classed, along with temperature, pressure and volume, as one of the variables defining the state of a body, and is often graphed as such on thermodynamic diagrams. (2) In information theory, entropy is a measure of the uncertainty of knowledge.

ENVIRONMENT. The aggregate of all the conditions and influences which affect the operation of equipments and components, e.g., physical location and operating characteristics of surrounding equipments and/or components; temperatures, humidity and contaminants of surrounding air; operational procedures; acceleration, shock and vibration; radiation; method of utilization, etc.

ENVIRONMENT, DERIVED. A classification comprising natural uncontrolled environments:

temperature	lightning
humidity	sand
rain	dust
snow	dirt
ice	fungus
sleet	pressure
hail	salt spray
wind and gusts	static electricity
fog	

ENVIRONMENT, INDUCED. A classification comprising environments caused by the operation, location and/or previous environmental state of a missile:

vibration	erosion (in flight)
shock	electromagnetic effects
aerodynamic heating	force

ENVIRONMENT, PRODUCTION-TO-TARGET. The physical conditions existing at each step described in the production-to-target sequence; they are given in terms of temperature range, pressure, humidity, shock, vibration, acceleration, etc., with the time duration of each condition usually included.

ENVIRONMENTAL ENGINEERING. That phase of engineering devoted to the study of cause and effect of the several environments in which equipment must live. Particularly for missiles this includes:

vibration	fungus
shock and impact	corrosion
temperature	pressure
climatology	

ENVIRONMENTAL MEDICINE. That branch of medicine devoted to the effects of environment on man. Its applications to conditions encountered in space flight are extremely important.

ENVIRONMENTAL PROTECTION. Unique steps taken to protect equipment from any or all of the following environments:

- shock
- vibration
- temperature
- corrosion
- abrasion (sand, dirt, dust, snow, hail, ice)
- moisture (humidity, snow, ice, hail, rain)
- pressure
- lightning
- wind
- sunshine
- noise
- fungus

ENVIRONMENTAL TESTING. In missile research and development where high reliability is an objective, simple laboratory testing of performance of components is not adequate. It is necessary to subject all missile assemblies to environmental test values such as shock and vibration, similar to or even more severe than will be encountered during actual flight. Using magnetic shake tables in vacuum chambers, it is possible to simulate the operating conditions for test purposes. Sensing instruments can be carried in early missile flights to record vibratory environments at selected points in the missile. Magnetic tape recordings of these can be played into the shake table to cause it to vibrate similarly to the missile environment. Any assemblies that fail such testing are rejected. Components to be used in a missile are sometimes shaken, shocked and pre-aged before actual flight use in the belief that such pre-use testing will reveal "bugs" and avoid flight failures. This practice is questionable for items to be placed in service since it may use up a large portion of the finite failure-free life which every component possesses. Environmental testing is normally used only for quality control purposes. Some types of

environmental testing are: Shock (destructive), high temperature, cold (nondestructive), vibration, dust, salt spray, and high humidity testing.

ENZIAN. A family of German World War II surface-to-air missiles developed by the Messerschmitt Aircraft Company in 1944. Each of them had a different rocket motor for propulsion, and some differences in airframe. A typical missile of the group was a bullet-shaped vehicle about 12 feet long with a body diameter of 3 feet.

EPHEMERIS. A tabulation of data for use in determining the orbit of an astronomical body (usually a planet or a comet) or an orbiting space vehicle. The data usually recorded are the celestial position of the object as seen from the earth, its **right ascension** and its **declination**. These observations are tabulated at regular intervals, often once a day, in an ephemeris. An Astronomical Almanac gives such tabulations for the sun, moon and principal planets for each year in advance.

EPHEMERIS TIME, Time.

EPIPOLES. In aerial photogrammetry, the points on the planes of two photographs where they are cut by the "air base" (line extended to join the two perspective centers). In the case of a pair of vertical photographs, the epipoles are infinitely distant from the principal points. The epipolar plane is any plane containing the epipoles, and hence the camera base.

E-PLANE BEND. For a rectangular uniconductor **waveguide** operating in the dominant mode, a bend in which the longitudinal axis of the guide remains in a plane parallel to the electric field vector throughout the bend.

EPOCH. The displacement of a body or entity undergoing **simple harmonic motion** at t (time) = 0.

EPOCH ANGLE. The angle between the thrust line of a missile or space ship and some reference plane just prior to the initiation of a new thrust period. It has a meaning similar to **angle of departure**.

EPUT COUNTER (EVENTS PER UNIT TIME). An electronic device for high speed counting.

EPUT METER. An electronic device which counts and records voltage pulses.

EQUALIZER. A network inserted in a system to modify the overall frequency response in a desired manner. This term is also used for the series of connections made in paralleled, cumulatively-compound d-c generators to prevent system instability.

EQUALIZER, LINE. An equalizer inserted in a transmission line to modify the frequency response in a desired manner.

EQUATION OF TIME. A mathematical formula by which apparent time may be found by adding or subtracting a certain number of time units to or from mean time in accordance with a prepared table.

EQUATION(S) OF STATE. A class of equations connecting those variables, such as temperature, pressure, and volume, which define the physical condition of a given substance and are called variables of state.

The ideal gas law and the Boyle-Charles law represent approximately the behavior of all gases, but if one wishes to be accurate, some modification of these must be sought which will take account of the differences between individual gases. The best known characteristic equation for gases is that of van der Waals. Using the same notation as for the ideal gas law, this may be written

$$\left(p + \frac{a}{v^2}\right)(v - b) = RT.$$

However, the volume is not in liters but is in terms of the volume of the same body of gas at standard temperature and pressure; the pressure is in atmospheres; the temperature in degrees absolute (see **Temperature Scales**); and R is the gas constant which has a value of 0.08205 liter-atmosphere per degree per mole. This value of R is independent of temperature for ideal gases, or for real gases if corrections are made for their departures from ideality, as by a and b in the van der Waals formula and by similar factors in certain other such formulas. a and b in the van der Waals formula are constants characteristic of the gas in question. They are very small; if they were zero we should have the ideal gas law. Following are their approximate values for certain gases:

GAS	a	b
Ammonia.....	0.00831	0.00165
Helium.....	0.00007	0.00106
Hydrogen.....	0.00049	0.00119
Nitrogen.....	0.00277	0.00175
Oxygen.....	0.00271	0.00142

Clausius modified van der Waals' equation as follows:

$$\left(p + \frac{a}{T(v + c)^2}\right)(v - b) = RT.$$

employing three empirical constants a , b , c ; while the equation of Dieterici has an exponential factor:

$$p \cdot e^{\frac{a}{RTv}} \cdot (v - b) = RT.$$

None of these equations represents the behavior of all gases equally well.

Beattie and Bridgman have proposed a characteristic equation for fluids in general, as follows:

$$pv^2 = RT \left(1 - \frac{c}{vT^3}\right) \left[v + B \left(1 - \frac{b}{v}\right) - A \left(1 - \frac{a}{v}\right) \right]$$

in which a , b , c , R , A , and B are empirical constants to be determined for each fluid.

EQUATOR. (1) An imaginary line cut on the surface of the earth by a plane perpendicular to the axis of rotation, and passing through the center of the earth. (2) An imaginary line cut by this plane on the celestial sphere. This line is often called the "celestial equator" or "equinoctial" to differentiate it from the terrestrial equator.

EQUATORIAL COORDINATES. Equatorial coordinates are a system of spherical coordinates in which the origin may be the eye of the observer (in which we have the apparent system of coordinates), the center of the earth (geocentric system), or the center of the sun (heliocentric system). The fundamental line in this system is the line joining the poles of rotation of the earth which cuts the celestial sphere in its poles of rotation. The plane perpendicular to the fundamental line through the origin is the celestial equator. The fundamental direction in the plane may be either the point of intersection of the local meridian with the celestial equa-

tor, which is above the horizon, or the **vernal equinox**.

To locate an object in this system of coordinates, a plane is passed through the object and the line joining the poles of rotation and this plane will cut out a great circle, known as an **hour circle**, on the celestial sphere perpendicular to the plane of the equator. The **declination** of an object is the angular distance of the object north (+) or south (−) of the celestial equator measured in the plane of the hour circle through the object. The **hour angle** of the object is the angular distance measured in the plane of the equator from the point of intersection of the meridian above the horizon to the point of intersection of the hour circle through the object in the direction of apparent rotation (west) of the celestial sphere. The right ascension of the object is the angular distance, measured in the plane of the equator from the vernal equinox to the point of intersection of the hour circle in a direction (east) contrary to the direction of apparent rotation of the celestial sphere. For purpose of convenience both right ascension and hour angle are frequently expressed in units of hour, minutes and seconds of time, rather than the more common angular notation of degrees, minutes, and seconds of arc.

Due to the fact that the local meridian remains fixed as the celestial sphere apparently rotates, the hour angle of an object is continually changing. Since both the vernal equinox and the hour circle rotate with the celestial sphere, both the right ascension and declination of the object remain fixed as the sphere rotates. However, both right ascension and declination change slowly due to **precession** and **nutation**. In tabulating these coordinates in star catalogues the values are given for the position of the equinox for some particular date and the corrections necessary to reduce the positions to the present date must be applied.

EQUATORIAL ELEMENTS. Satellite elements.

EQUIDISTANT AZIMUTHAL PROJECTION. A map so designed that all radial lines drawn from its center are true in distance and direction.

EQUILIBRIUM. A condition in which all the forces or tendencies present are exactly

counterbalanced or neutralized by equal and opposite forces and tendencies. In a state of equilibrium, at least some of the quantities describing the system are independent of time. Usually synonymous with a stable system.

EQUILIBRIUM PRESSURE. In a solid propellant rocket, the internal gas pressure which provides a rate of gas discharge through the nozzle equal to the rate of gas generation. (It depends upon rocket geometry, the burning rate of the propellant, and the initial temperature of the grain. The relationship between pressure and hence, thrust, and initial grain temperature is approximately linear. The impulse does not change appreciably over the usual temperature ranges, therefore, the change in thrust is accompanied by an inverse change in duration.)

EQUINOCTIAL. Equator.

EQUINOX. One of the two points at which the line of intersection of the plane of the earth's **equator** and the plane of the **ecliptic** intersects the **celestial sphere**. As seen from the earth the sun apparently passes through each of the equinoxes once each year, passing through the vernal equinox on approximately March 21, and through the autumnal equinox on approximately September 21.

EQUIPMENT. A combination of parts, assemblies or subassemblies capable of functional operation by itself (except the primary power supply as specified); e.g., an antenna, antenna tuner, radio transmitter and transmitter modulator, radio altimeter, turbo-pump, fuze, etc.

EQUIPMENT COMPONENT. A group of parts, subassemblies or assemblies combined in a separate housing and used as an element of an equipment: e.g., antenna tuner, radio transmitter, or transmitter modulator if each is in separate housing.

EQUIPMENT COMPONENT LIST (ECL). A publication that prescribes the components of individual kits and organizational sets of equipment required for the performance of specific duties, functions, or support of end items of equipment.

EQUIPMENT (HARDWARE) SPECIFICATION. A government specification which spells out in some detail the requirements for

equipment. An extreme example is a set of working drawings; a minimum example is a set of schematic drawings.

EQUIVALENCE RATIO. The ratio of the stoichiometric air-to-fuel ratio to the experimental air-to-fuel ratio in an air-breathing engine.

EQUIVALENT ALTITUDE. An altitude that would supply the same amount of oxygen to the respiratory system as that provided in a pressurized cabin or through an oxygen mask.

EQUIVALENT BRAKE HORSEPOWER. The brake horsepower equivalent to the thrust of an engine, especially a jet engine or rocket engine.

EQUIVALENT FOCAL LENGTH. The distance measured along a lens axis from the rear nodal point to the plane of best average definition over the entire field.

Er. Erbium.

ERASING HEAD. A device for obliterating any previous recordings on a tape or wire recorder. It may be used for preconditioning magnetic media for recording purposes.

ERECTION. (1) The action of raising a missile into the vertical position and placing it on its launching platform, or the act of raising a moveable launcher which holds a missile to the vertical firing position. (2) The process of causing a gyroscope axis to be aligned in the proper direction so that when it gains speed it will maintain itself in the desired space-fixed orientation. Since one gimbal or another of a gyroscope mounting is usually vertical during active use, the term is applied to indicate that the gyro has been picked up from its random lying-down position and caused to maintain itself in the desired flight orientation by its rotating forces.

ERECTOR. A system of raising or lowering the complete missile, or its stages, from the horizontal to the vertical position. (See **Erection** (1).)

ERG. A unit of work or energy in the cgs system of units, being the work done when a steady force of one dyne produces a displacement of one centimeter in the direction of the force.

EROSION, PROPELLANT. The deformation of a solid propellant due to heat, radiation, and gas friction, leading to **erosive burning**.

EROSIVE BURNING. The accelerated burning of a solid propellant due to the action of the gas flow parallel to the burning surface. In propellant grain design, it is generally assumed that the effects of gas velocity upon burning rate can be evaluated by one of several empirical equations which involve the grain dimensions and one or more "erosive burning constants."

ERRATIC MISSILE. A missile which uncontrollably deviates from its planned flight path to such a degree that it fails to accomplish its mission, exceeds the range safety limits or otherwise becomes a cause of concern. The term refers to the flight path performance and not necessarily to missile system performance.

ERROR. The quantity which must be subtracted from an observed or calculated quantity to yield a closer approximation to the true value. The error is equal in magnitude and opposite in sign to the **correction**.

ERROR, ACCIDENTAL. A random unpredictable error due to known causes.

ERROR, INSTRUMENTAL. Any error in measurement which results from the properties of the instruments used in the measurement. Instrumental errors may be divided into scale errors, which result from improper calibration of the instrument, and reproducibility errors, which result from the failure of the instrument to give the same indication whenever it is subject to the same input signal. The latter type may be treated as accidental errors, the former may not.

ERROR, PERSONAL. Any error which results from the tendency of an observer to misread an instrument, e.g., to read consistently high or low. Personal errors are not distributed in the same manner as accidental errors, and their magnitudes may be estimated only by the comparison of observations made by different observers.

ERROR, PROBABLE. Probable error.

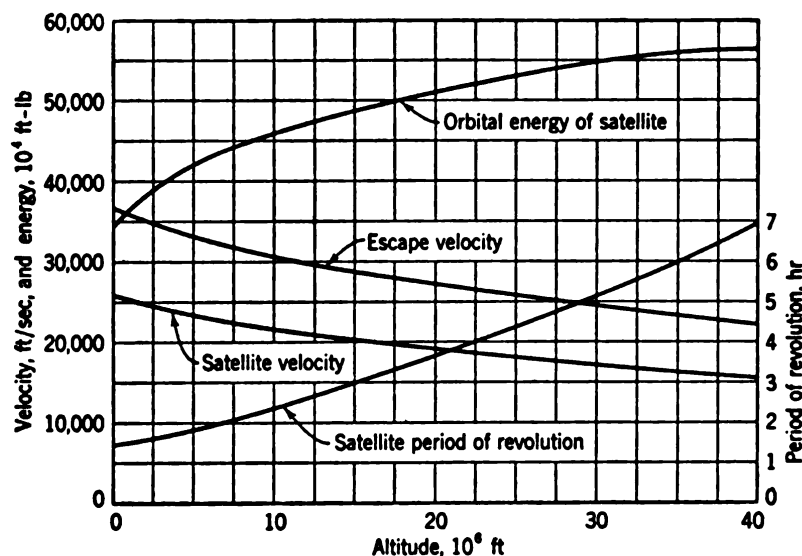
ERROR SIGNAL. (1) In servomechanisms, the signal, frequently a voltage, applied to the

control circuit that indicates the misalignment between the controlling and the controlled members. (2) In tracking systems, a voltage, depending upon the signal received from the target, whose sign and magnitude depends on the angle between the target and

E_s . Signal voltage.

Es. Einsteinium.

ESCAPE ENERGY. The energy per unit mass which must be imparted to a missile to give it the **escape velocity**. (See figure.)



Orbital energy, orbital velocity, period of revolution, and escape velocity of a satellite vehicle as functions of altitude. A circular satellite orbit is assumed.

the center of the scanning beam. (See **conical scan**.)

ERROR, SYSTEMATIC (BIAS). An error that is constant, or that varies in a predictable manner (e.g., an error due to instrument misalignment). It is usual to assume systematic errors to be constant in direction and magnitude, or if not, to introduce calibration curves for correction of the final measurement. Systematic errors may occur in the data collection **end instrument**, the data transmission system, or the reduction process, but their nature provides that they cannot be eliminated by any form of averaging computation. Systematic errors include: theoretical errors (external errors), instrumental errors, and personal errors.

ERROR, THEORETICAL (EXTERNAL ERROR). An error due to natural causes, e.g., atmospheric refraction, thermal expansion, atmospheric pressure, etc. (See also **calibration curve** and **linearization**.)

ERYTHEMAL FLUX. Radiation which produces reddening of the skin, and on continued action, sunburn.

ESCAPE MANEUVER. Maneuver, **escape**.

ESCAPE VELOCITY. The speed necessary effectively to escape from the gravitational pull of a body. It is evaluated by calculating the speed attained by an object in falling from an infinite distance to the body whose escape velocity is being computed. For the earth, this calculation yields a value of about seven miles per second. Therefore, an object leaving the surface of the earth with that velocity could in theory (disregarding the other bodies in the universe) travel indefinitely. Escape velocity is an important characteristic of a planet, upon it depends whether that planet can retain an atmosphere, for if the gas molecules have average speeds comparable with the escape velocity, the atmosphere would leak away into space, as supposedly has happened in the case of our moon. Escape velocity is sometimes called **parabolic velocity**. A projectile accelerated from the earth's surface at a speed below that of escape travels away from the earth in an elliptical path gradually losing speed until at the point farthest from the earth (apogee), it turns earthward and begins to travel back to the

earth, under the influence of its gravitational field; but still following the elliptical path. If the velocity of the projectile were sufficient (orbital velocity) it would establish a permanent orbit beyond the sensible atmosphere of the earth, becoming a satellite. When the projectile velocity is sufficient for escape from the earth's gravity field, its path becomes a parabola (or hyperbola) hence the term parabolic velocity. The escape velocity from the earth is given by the following relationship:

$$V_e = R_e \sqrt{\frac{2g_e}{R_e + h}}$$

where R_e is radius of the earth, g_e is the gravitational acceleration of earth, and h is the altitude at take-off. The work to move a unit mass from the surface of the earth to infinity is given by:

$$E = \int_{R_e}^{\infty} g \frac{R^2}{r^2} dr = gR$$

and the work to move a unit mass from some external point r to infinity is given by:

$$E = \int_r^{\infty} g \frac{R^2}{r^2} dr = \frac{gR^2}{r}$$

From the former the energy required to project a body to infinity from R_e requires a kinetic energy of gR per unit mass. So the escape velocity becomes:

$$V_e = \sqrt{2gR_e}$$

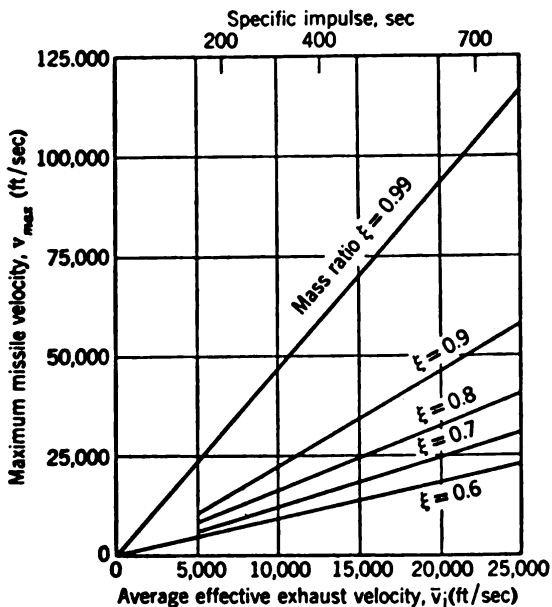


Fig. 1. Maximum missile velocity in gravitationless drag-free space for different mass ratios.

To determine whether a missile can attain escape velocity, see the following maximum missile velocities under various conditions. (See also **gravitation** and **planet**.) (Fig. 1-Fig. 4).

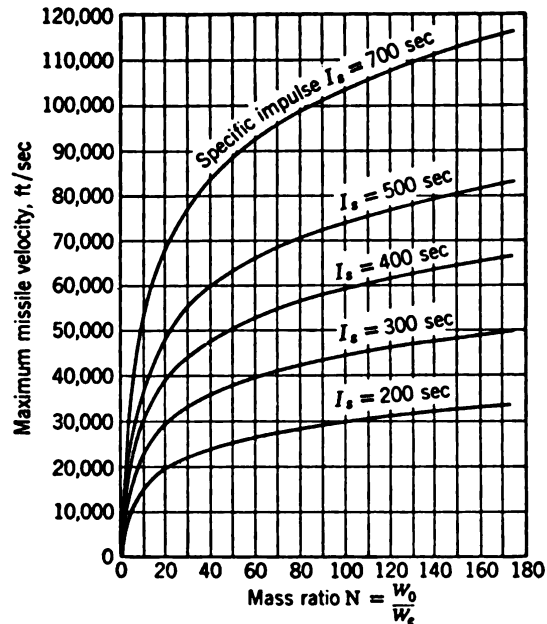


Fig. 2. Maximum missile velocity in gravitationless drag-free space for different specific impulses.

E-SCOPE. A radarscope that presents the range of an object by a horizontal displacement of the signal spot and its elevation by a vertical displacement.

ETHANE. An organic gas useful as a fuel. Its chemical formula is C_2H_6 . It has a boiling point of $-126^\circ F$ and a freezing point of $-278^\circ F$. Its specific gravity at $-100^\circ C$ is 0.561, and its specific heat at constant pressure is 0.307.

ETHER. (1) A volatile inflammable liquid of the chemical formula, $(C_2H_5)_2O$. It has a characteristic aromatic odor. Its complete chemical name is diethyl ether. (2) A chemical compound of the same type formula as diethyl ether (that is, containing an oxygen atom linking two carbon atoms) but having one or both of the ethyl groups replaced by other alkyl or aryl groups. (3) A hypothetical fluid that was postulated to fill all space and to act as a medium for the propagation of electromagnetic waves. The theory was abandoned when Newtonian dynamics were modified by the special relativity theory.

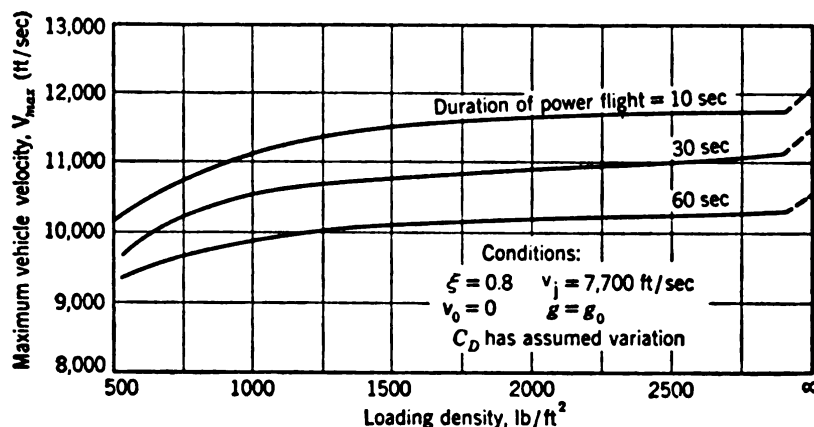


Fig. 3. Maximum velocity as a function of loading density.

ETHYL ALCOHOL. Ethanol, or grain alcohol. It is an organic compound of chemical composition C_2H_5OH frequently used as a fuel for liquid **propellant** missiles. Ethyl alcohol for use in missiles is commonly mixed with distilled or deionized water. Ethyl alcohol has a low heat value, low vapor pressure. It has a melting point of $-175^\circ F$ and a boiling point of $173^\circ F$. Its density at $68^\circ F$ is 0.789 gm/cm^3 .

ETHYL NITRATE. An organic compound of formula $C_2H_5NO_3$ having applications as a monopropellant rocket fuel. It has a boiling point of $192^\circ F$, freezing point of $-152^\circ F$, and specific gravity of 1.105.

ETHYLAMINE. A chemical compound of formula $C_2H_5NH_2$ considered as a possible

rocket fuel. It has a boiling point of $63^\circ F$, a freezing point of $-114^\circ F$ and a specific gravity of 0.706.

ETHYLENE. A gaseous chemical compound of formula C_2H_4 considered as a rocket fuel. It has a boiling point of $-155^\circ F$, a freezing point of $-290^\circ F$ and a specific gravity of 0.566.

ETHYLENE GLYCOL. An organic compound of formula $C_2H_6O_2$ used as a "permanent" type of antifreeze solution in liquid-cooled engines. It is colorless, non-poisonous, non-inflammable, non-corrosive, non-toxic and non-electrolytic. It has a boiling point of $350^\circ F$ ($177^\circ C$) and a freezing point of $-48^\circ F$ (to freeze solid).

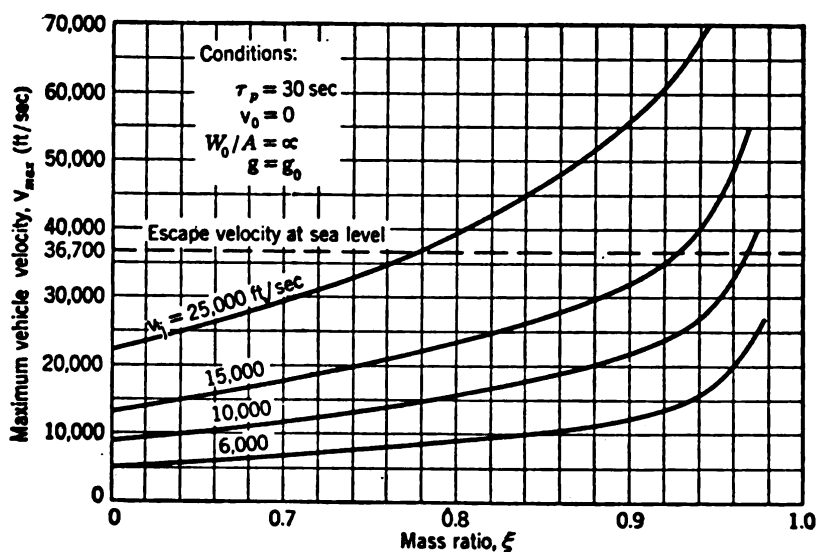


Fig. 4. Velocity at end of burning as a function of mass ratio.

ETHYLENE OXIDE. An organic compound of formula C_2H_4O used as a bipropellant or a monopropellant for rocket motors. Its boiling point is $52^\circ F$ and freezing point is $-168^\circ F$ ($-111.3^\circ C$). Specific gravity is 0.870. It is a colorless gas condensing at $10.7^\circ C$ (at 1 atmosphere). It decomposes violently at $571^\circ C$. It is generally non-corrosive.

Eu. Europium.

EUTECTIC. A minimum temperature and corresponding composition (in other words, a minimum point upon a temperature-composition diagram) at which a liquid consisting of two or more components is in equilibrium with its components in the solid state, or with a particular group of solid substances derived from its components, and which may include one or more elements, compounds or solid solutions. (See **alloy**.) Material of this composition is often called an "eutectic"; and the temperature of this point is sometimes called the eutectic temperature. It represents the lowest melting point of the system. This temperature is constant, and is analogous in many respects to constant boiling mixtures of liquids.

EUTECTOID. In binary alloy systems a eutectoid alloy is a mechanical mixture of two phases which form simultaneously from a solid solution when it cools through the eutectoid temperature. Alloys leaner or richer in one of the metals undergo transformation from the solid solution phase over a range of temperatures beginning above and ending at the eutectoid temperature. The structure of such alloys will consist of primary particles of one of the stable phases in addition to the eutectoid, for example ferrite and pearlite in low-carbon steel.

EVAPOGRAPH PROCESS. A photographic process using infrared radiation. In it an oil film is produced on a suitable "plate," and infrared radiation from an object is focused on the oil film. The oil evaporates at a rate proportional to the radiation received at each point. An image is thus formed and can be photographed by conventional cameras. It is not a rapidly acting system, and cannot be used for moving objects.

E-VECTOR. The vector representing an electric field; the term being used especially

in relation to **electromagnetic waves**, where both electric and magnetic fields are involved. In free space the E-vector of an electromagnetic wave is perpendicular to the direction of propagation, and also to the **H-vector** representing the associated magnetic field.

EWR. Early Warning Radar.

EX-8. An Aerojet General project for the development of an ultra-high speed underwater anti-submarine missile.

EXCITATION. (1) Addition of energy to a system, whereby it is transferred from its ground state to a state of higher energy, called an "excited state." (2) The field excitation of dynamo machines, meaning the current or voltage of the field circuit. (3) In electron-tube circuits, the input signal of any stage is commonly called the excitation. Thus in a radio receiver, the signal picked up by the antenna supplies the excitation for the first stage, the output of the first supplies the excitation for the next, and so on.

EXCITATION DRIVE. A signal voltage applied to the control electrode of an electron tube.

EXCITATION, SHOCK. The type of excitation supplied by a voltage or current variation of relatively short duration. The term is also used to indicate the initiation of motion in a mechanical system by an **impulse** of short duration.

EXCITER. (1) In antenna terminology, the portion of a transmitting array of the type which includes a **reflector**, which is directly connected with the source of power. (2) In transmitters, the **oscillator** which supplies the carrier or subcarrier frequency voltage to drive the stages which ultimately lead to the final power output stage. In FM systems this unit includes all the frequency generating, modulating and frequency multiplying circuits of the transmitter. (3) In photoelectric reproduction of film, the lamp which supplies a light source of constant amplitude. (4) A generator used to supply the field currents of a larger direct current generator or of an alternator.

EXCITING CURRENT. Synonym for **magnetizing current**.

EXHAUST CONE. An assembly at the aft end of a gas-turbine engine, consisting of a cone-shaped inner part surrounded by a casing shaped like a truncated cone, the jet exhaust being conducted through the space between the two pieces. Also called a "tail cone."

EXHAUST NOZZLE. A nozzle through which exhaust gases are ejected, as from a jet or rocket engine.

EXHAUST VELOCITY. The velocity at which a propelling fluid is discharged from a thermal engine. The exit or exhaust velocity of a thermal engine depends on several parameters which can be subdivided into thermochemical parameters and motor parameters. Thermochemical parameters are: energy content of the fuel, mixing ratio of the propellants, expansion pressure ratio, and degree of combustion. Motor parameters are: thrust, mass of weight flow of propellant, nozzle divergence, difference between nozzle exit pressure, and ambient pressure. Although some of the thermochemical parameters, such as expansion ratio and degree of combustion, are strongly influenced by the motor design, they must be known, or at least be assumed for thermochemical performance calculations. The second group of parameters contains quantities which serve to measure the exhaust velocity (thrust, weight flow), or which depend on the motor design (divergence angle), or on operational conditions, such as the exit-ambient pressure difference. In a given motor, the nozzle dimensions are fixed, hence, for a given chamber pressure, the exit pressure is determined. Therefore, a variation of the pressure difference is due to change of ambient pressure as it occurs during powered ascent.

The exhaust velocity defined by the first group of parameters describes the propellant performance, independent of motor design and operational conditions, and indicates the **impulse**, that is, the thrust for a given mass flow and length of time, which can be expected from the propellant in question. Therefore, this velocity is termed "impulse exhaust velocity." If divided by the gravitational constant, it yields the **specific impulse**, a parameter which depends only on thermochemical data and the expansion ratio.

The second group of parameters defines an exhaust velocity which describes the motor

performance. It is determined by the thrust, obtained at a given propellant consumption, and varies with changing ambient pressure. For instance, the over-all thrust increases as the difference of exit minus ambient pressure increases (pressure thrust). Instead of accounting separately for the pressure thrust (as distinguished from the momentum thrust, produced by the discharge of matter), one can add this effect to the momentum thrust (defined as the product of mass flow and exhaust velocity). If, in an ascending rocket the over-all thrust increases and the propellant mass flow remains constant, the exhaust velocity necessarily increases. This illustrates that exhaust velocity is not the physical or thermochemical exhaust velocity but an equivalent velocity which converts instantaneous operational conditions into equivalents of a standard condition (namely exit pressure equal to ambient pressure, i.e., no pressure thrust). For this reason exhaust velocity is better termed "equivalent exhaust velocity." If this velocity is divided by the gravitational constant, one obtains the specific thrust.

EXHAUST VELOCITY, EFFECTIVE. The effective exhaust velocity of a rocket engine is the average axial velocity of the jet stream leaving the exhaust nozzle.

EXHAUST VELOCITY, MAXIMUM THEORETICAL. A velocity whose calculation is based on the assumption that the propellant lower heat of combustion is converted completely into kinetic energy of the exhaust gases. The lower heat of combustion, Q_L , represents the heat energy released by the combustion products when cooled down to an initial datum temperature (usually 60° or 70°F) neglecting the latent heat of fusion. The term Q_L , therefore, represents the maximum possible quantity of heat that possibly can be converted to kinetic energy of the gas. It yields the maximum theoretical exhaust velocity.

EXHAUST VELOCITY, THEORETICAL. Theoretically, the full amount of the lower heat of combustion could be utilized in an engine to provide an expansion of the gas down to the datum temperature; this yields a theoretical exhaust velocity. For actual operation, however, this would not be practical, even if the resulting low exit pressure could

be attained without overexpansion, since it requires an extremely large area ratio of the nozzle. This ratio could be obtained either by using a short nozzle with a large angle of divergence, or a very long nozzle with a moderate angle of divergence. In the first case, considerable losses result from a decrease in the magnitude of the useful velocity component which lies parallel to the motor axis, in favor of the component normal to the axis. The latter component is of no use for the propulsion. In the second case a very long nozzle would increase the motor weight excessively and thus reduce the overall rocket performance more than the additional heat utilization would increase it. There exists an optimum compromise between nozzle geometry and heat energy utilization.

EXOS. A high altitude sounding rocket developed by the U.S. Air Force Cambridge Research Center. It was intended to reach the lower exosphere (300-450 miles), with a 50 pound payload. It was assembled from existing hardware as follows: 1st stage—**Honest John**, 2d stage—**Nike booster**, and 3d stage—**Recruit** (all solid propellant rockets).

EXOSPHERE. The outermost layer of the atmosphere in which the air particles travel in elliptical orbits with infrequent collisions. It is approximately $\frac{1}{3000}$ of the earth's atmosphere in terms of mass, and located at an average distance of 500-600 kilometers from the surface of the earth.

EXOTHERMIC CHANGE. A physical or chemical change which proceeds with the development of heat.

EXOTIC FUELS. **Fuels, exotic.**

EXPANDER. The part of the communication circuit designed to expand the volume range back to the original value as it is normally compressed for transmission.

EXPANSION AREA RATIO. The ratio of the cross-sectional area at the exit of a rocket motor, or the exit section of a nozzle, to the cross-sectional area of the throat of the motor or nozzle. This quantity is sometimes denoted by the shorter expression, expansion ratio, but in that case it should be distinguished from the other meaning of the latter term. (See **expansion ratio** (1).) (See also **contraction ratio**.)

EXPANSION FAN. **Expansion wave.**

EXPANSION RATIO. (1) The ratio of the pressure at a point just outside the rear lip of an exhaust nozzle to the pressure in the combustion chamber. This ratio is important because of its relationship to the **exhaust velocity** of the rocket. (2) The ratio of the area of the exit section of a nozzle to its throat. However, the more common term for this ratio is **expansion area ratio**.

EXPANSION WAVE. An expanding air flow. In supersonic aerodynamics, such flows are often produced by means of a receding configuration, as for example the junction of a nose cone and the cylindrical afterbody of a typical missile. The changes in thermodynamic parameters on passing through an expansion wave are as follows:

DECREASE	NO CHANGE	INCREASE
Pressure (p)	Total temperature (T_0)	Mach number (M)
Speed of sound (c)	Entropy (S)	Velocity (v)
Density (ρ)		
Temperature (T)		
Total pressure (P_0)		
Enthalpy (H)		
Refractive index (μ)		

An expansion wave is also called an expansion fan or Mach fan. (See also **shock wave**.)

EXPANSIVE FLOW. In supersonic aerodynamics, flow which meets an expanding passage. Contrary to subsonic expansions, the velocity increases, and unlike compressive supersonic flow, all thermodynamic changes are gradual and continuous.

EXPLORATORY ROCKET. A rocket built and equipped to explore the upper atmosphere or beyond.

EXPLORER. The Explorer satellite series is under the direction of the U.S. Army and is based on the **Redstone** missile and three cluster-type upper stages developed at the Army Ballistic Missile Agency (ABMA) Redstone Arsenal under the direction of Dr. W. von Braun. This satellite vehicle is designated Juno I. Its prototype was the **Jupiter-C** which in 1956-7 was used for IRBM nose cone re-entry tests. The modifications of Jupiter-C to become Juno I were as follows: The tanks of the first stage were enlarged and the wall thickness reduced to save weight. The regular fuel was replaced by a

hydrazine-based compound, code-named "Hydyne" and developed by the Rocketdyne Division of the North American Aviation Corporation; the properties of Hydyne resemble the original fuel, alcohol. Hydyne increases the specific impulse by about 12 percent. A fourth solid propellant stage was added, carrying the satellite itself. The satellite was developed by the Jet Propulsion Institute of the California Institute of Technology.

Aside from the first stage, whose engine was developed by North American, the upper stages were solids, developed by the Jet Propulsion Laboratory. The second stage consisted of a ring of 11 rockets arranged in a circle inside a cylinder which is clearly visible on the nose of the modified Redstone. The third stage, a cluster of three rockets, is stored inside the second-stage circle. The fourth stage was mounted on top. It consisted of one solid propellant rocket, designed to remain as one unit with the satellite in orbit. The unit was not recoverable.

The guidance system and two electromotors to spin the second-stage cylinder were housed in the nose of the first stage. The final speed of rotation of the composite set of upper stages was about 760 rpm. This speed has the purpose of neutralizing possible unsymmetries due to clustering, and to provide attitude stabilization (that is, maintenance of a fixed direction, in contrast to attitude control) during the powered flight of the upper stages which are not equipped with a guidance and control system. The spinning of the cylinder was started on the ground and stepped up shortly before separation, because of the dynamic characteristics of the vehicle. Due to this arrangement, the powered trajectory could not be deflected gradually from stage to stage. The first stage carried the cluster beyond the atmosphere in nearly vertical flight, coasting to a summit altitude of about 188 nautical miles. Shortly before this point was reached, the first stage was separated and the cylinder brought in to horizontal position by means of compressed air jets. Thereafter the second stage was ignited by ground command. Subsequently the other stages ignited automatically upon cut-off of the preceding stage. After a brief time of about 18 seconds (while still horizontal) the last stage reached orbital speed. (For orbital data, see table in entry for **satellite, artificial**.)

The satellite itself consisted of the empty shell of the fourth stage and an instrument section. The overall length of this system was about 6.65 ft. long and 1 ft. in diameter, carrying about 11 pounds of electronic and instrument payload. The following measurements were made:

1. Measurement of rate and intensity of cosmic primaries outside the Earth's atmosphere. This experiment was designed by Dr. James Van Allen of the State University of Iowa. The measurements were made by a Geiger-Müller counter. The counter was laid out for handling an excess of 40 times the expected radiation dose, as it might occur during increased sunspot activity.

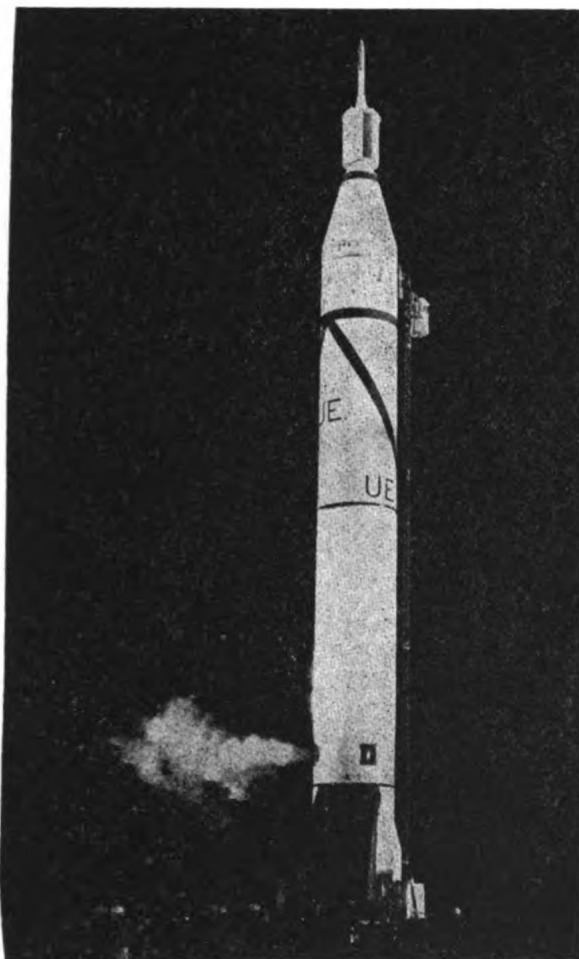
2. Measurement of micrometeorite distribution. This experiment was performed by the Air Force Cambridge Research Center, Geophysics Research Directorate, based on a suggestion by Dr. M. Dubin and Dr. E. Manning. The measurements were made using microphones to pick up the impact of particles on the wall and transmit the information to the ground.

3. Measurement of the abrasive effect of clouds of micrometeorites. The erosion gauge consisted of 12 very fine wires, arranged in parallel. As erosion takes place, wires may be cut, changing the current flowing through the gauge. The instrument was located near the aft end of the fourth-stage motor. It was capable of detecting interplanetary dust particles of five microns (0.0002 inch) in diameter, or larger.

4. Measurement of temperatures by means of thermoelements. The temperature was measured between instrument section and fourth stage, between instrument section and nose cone, in the center of the instrument section and at the high-power (0.06 watt) transmitter.

The information was transmitted to ground stations distributed all over the earth (all nations participating in the IGY were informed about the frequencies and the code) by means of a high-power and a low-power transmitter. The former transmits on a frequency of 108.03 megacycles at 60 milliwatts power. It used the Vanguard Minitrack stations and could be received by radio amateurs. It transmitted cosmic ray counts, micrometeorite impact data, temperature inside the instrument section and the skin temperature at the rear. The low-power transmitter oper-

ated on a frequency of 108 megacycles at 10 milliwatts power. This transmitter used a bandwidth of only a few cycles, which greatly reduces the power requirement (Microlock system), but prevented reception by radio amateurs. It provided information on micro-meteoritic abrasion, forward temperature and cosmic ray counts. Both transmitters had separate power supplies to increase the reliability.



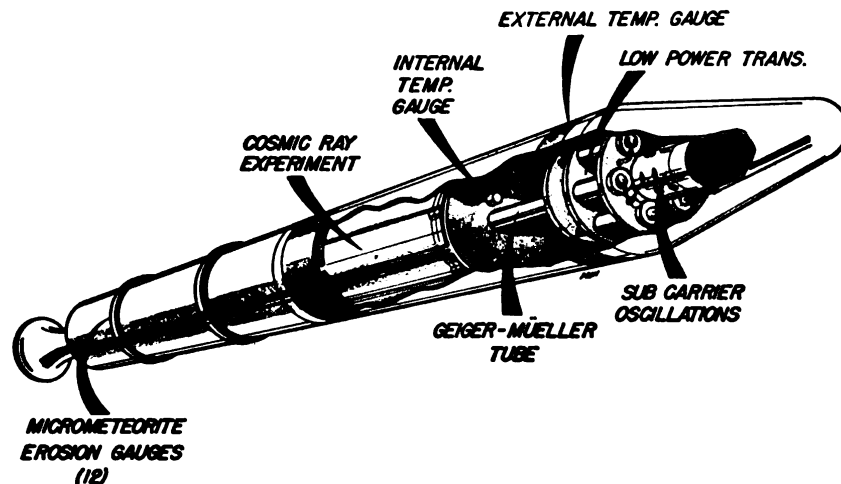
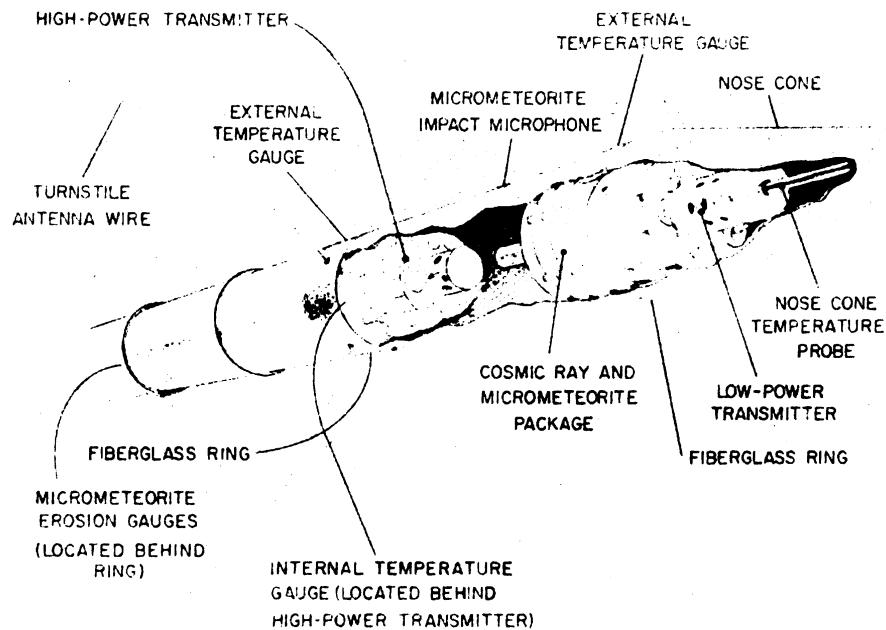
Juno I, four-stage vehicle carrying first U.S. satellite, Explorer I, into orbit. Army Ballistic Missile. (Official U.S. Army Photo.)

Explorer I had no storage capacity, so that only instantaneous information could be received by a given ground station as long as the satellite is within its range. Explorer III, launched on March 3, 1958, in the same manner as Explorer I, is equipped with a storage mechanism, so that integral measurements, especially of cosmic radiation and tempera-

ture variations can be made. Explorer IV, weighing 34.43 pounds, was launched on July 26, 1958, and was reported to have an apogee at 1386 miles, a perigee at 178 miles, and a period of 110.2 minutes.

In order to control the wide temperature range between the day and night arcs of the orbit, the Explorer instrument section is coated with strips of zirconium oxide which cover about 15 percent of the metallic surface. The high reflectivity of the oxide increases the average **albedo** of the surface. This, together with physical (i.e., vacuum) separation of outer wall and wall of the instrument section, as well as the use of Fiberglas for the inner wall, serves to maintain a moderate temperature with low-amplitude variations in the interior of the satellite. The information transmitted by the satellite indicates a temperature variation between 43 and 113°F, compared to a skin temperature variation between 32 and 159°F as measured by the satellite.

Radiation measurements with the two Explorers resulted in two interesting findings. Preliminary evaluation of the Explorer I data indicated that the intensity of the cosmic primary radiation at the apogee (about 1,460 nautical miles) is only about 12 times as strong as on the surface. This means that the danger to humans from cosmic radiation (primaries) in space might have been overestimated. The other message is less happy and underscores the fact that we really know very little of what is going on in our immediate vicinity, i.e., in terrestrial space. Radiation measurements with Explorer III indicated a corpuscular radiation intensity above 900-1,000 nautical miles which is 300-400 times as intense as anticipated, completely saturating the counters. This radiation is softer than the cosmic primary radiation and may consist of high-energy electrons emitted from the Sun and trapped in the Earth's magnetic field. Nevertheless, the intensity is so high that, according to a preliminary estimate by Dr. Van Allen, man would risk severe radiation damage by staying at this or greater altitude, unless his space cabin and space suit were heavily shielded with a lead inner liner. This would represent a considerable weight penalty. Explorer IV reported cosmic radiation dosage of 100 roentgens per hour at a point 1200 miles over South America. Fortunately, at the altitudes at which the first in-



Interior of Explorer I and III. Missing from Explorer III is the turnstile antenna for the high-power transmitter which appeared on Explorer I and II. Explorer II failed to enter orbit. (Courtesy Jet Propulsion Laboratory, California Institute of Technology.)

habited satellites, as well as assembly and fueling stations are most desirable, namely at 300 to 600 nautical miles altitude, this radiation was not observed. However, it is too early to assess with finality, on the present information, the effect of this radiation on manned astronautics. The nature and origin of the radiation is not yet fully understood; it is not known how far out it extends. Finally it is not known whether the radiation in its presently indicated intensity is a steady or a transient phenomenon and, in the latter case, in which direction the intensity would

change. Explorer V was fired on August 24, 1958 but failed to orbit due to collision of the first stage booster with the multistage unit after burnout of the booster.

EXPLOSION. A chemical or nuclear reaction producing a violent expansion of the substances involved or in contact. A high order explosion is one occurring in a period of several milliseconds or less. A low order explosion is a partial or slow explosion, or especially an inadequate explosion due to faulty burning of explosive.

EXPLOSIVE. Any substance which undergoes a rapid chemical change, normally forming gases of much greater volume than the original substance. Low explosives are the propellants or other materials, such as gunpowder, which deflagrate at combustion rates on the order of $\frac{1}{4}$ second. High explosives (or brisant explosives) such as TNT, nitroglycerine, etc., detonate rather than deflagrate at combustion rates on the order of one millisecond. Initiators are extremely sensitive high explosives (e.g., the fulminates). Pyrotechnics are substances which normally do not explode, but react to deliver controlled amount of smoke, light, or flame. Nuclear explosives derive their energy from a transformation of mass to energy in a **nuclear reaction of fission or fusion.**

EXPLOSIVE CHAIN. Explosive train.

EXPLOSIVE "D." An explosive whose main constituent is ammonium picrate. It is relatively insensitive to shock and friction.

EXPLOSIVE DECOMPRESSION. A very sudden decrease in pressure, such as that occurring when a pressurized compartment or

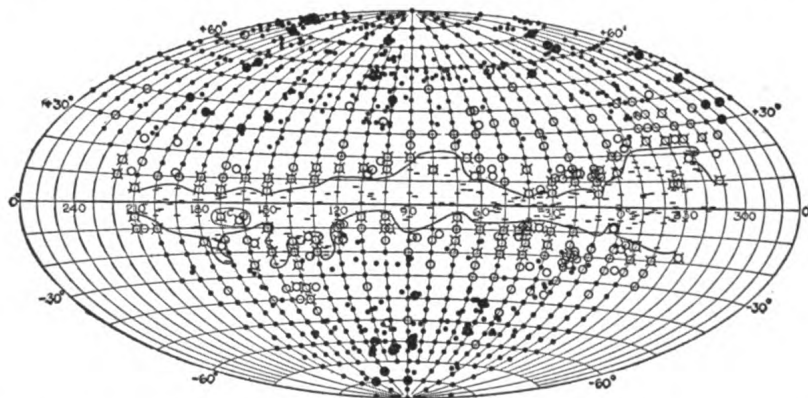
EXPONENTIAL DECAY. A characteristic reduction in amplitude, activity, etc., which occurs frequently in nature. It is the decrease in the amount of a particular substance present according to the equation $A = A_0 e^{-\lambda t}$, where A and A_0 are the quantities present at times t and zero, respectively, and λ is a constant characteristic of the substance involved in the process.

EXPONENTIAL HORN. Horn, exponential.

EXTERIOR BALLISTICS. Ballistics.

EXTERIOR ASTRONOMICAL SYSTEMS.

The galactic system (see **Milky Way**) belongs to a group of at least 17 members, which include the Large Magellanic Cloud, the Small Magellanic Cloud, the Sculptor System, the Fornax System and other systems, most of which are designated by letters and numbers. Using the Mount Wilson Telescope, Dr. Hubble made a photographic survey of other systems in which he counted the number of systems visible in each of 1283 sample areas over 75% of the heavens. The diagram in the figure shows some of the data he obtained.



Obscuration of exterior systems by dust clouds of the Milky Way. In this representation of the celestial sphere the numbers around the edge are galactic latitudes. Full dots indicate regions where the exterior systems are more numerous than average, circles where they are less numerous than average, and dashes where they are not seen at all. (Diagram by Edwin Hubble, Mount Wilson Observatory.)

chamber is opened suddenly to an external region (e.g., the upper atmosphere or space) which is at a much lower pressure.

EXPLOSIVE TRAIN (EXPLOSIVE CHAIN). In missile armament, a series of explosive elements including **primer, detonator, and booster**, arranged to permit war-head explosion to be initiated by relatively weak fuze signals.

The numbers are the greatest around the galactic poles; they become fewer with decreasing galactic latitude, until near the equator there are almost no systems to be seen at all. The exterior systems were originally called "extragalactic nebulae" because they seemed to avoid the Milky Way. We may assume, however, that they would be more or less uniformly distributed over the face of the sky, except where they are assembled in

clusters, if there were no dust clouds in our own system to hide them.

EXTERNAL INSTRUMENTATION. The data-gathering instrumentation on a proving ground used to obtain information about a missile, primarily without the use of auxiliary devices in the missile itself. An example of a system of external instrumentation is an airborne or ground-based radar set used for tracking. The missile may carry a beacon, which, however, is only incidental to the data gathering system. On the other hand, a TV camera carried within a missile to photograph instruments, control surfaces, or the earth passing below is an internal instrumentation system. Telemetry systems are also classed as internal.

EXTINCTION VOLTAGE. The potential at which ionization of a gas, such as that within a gas-filled tube, ceases, as determined by its conduction and related properties.

EXTRA-GALACTIC. Pertaining to spaces or objects outside our galaxy (the Milky Way).

EXTRA-PLANETARY SPACE. Space, extra-planetary.

EXTRAPOLATION. A process by which relationships are established between known

values of variables and projected values, i.e., those beyond the range of the known values. It uses the assumption that the relationship established by observation or experiment may be extended to values of the variables beyond the observed or experimental values. (Cf. interpolation.)

EXTRATERRESTRIAL. Outside of the earth's atmosphere.

EXTRUSION. The process of shaping material (including heated metals) by forcing them through an opening or die under pressure. An extruded part has a smooth surface, and relatively homogeneous structures.

EYEPIECE. The lens, or system of lenses, which is closest to the eye in an optical instrument such as a telescope or a microscope is known as the eyepiece or ocular. The eyepiece is usually a magnifying device used for the purpose of detailed examination of the real image formed by the objective of the instrument. It is usually designed to act as a collimator to the light from the objective so that the light from each point of the image formed by the objective emerges in parallel or nearly parallel rays. Hence in using a telescope or microscope in proper adjustment, the eye should be focused as though looking at a distant object.

F

F. (1) Function (f). (2) Force (F or f). (3) Formality (F). (4) Frequency (f). (5) Photoelectric threshold frequency (f_0 but ν_0 is preferred). (6) Fugacity (f). (7) Faraday constant or equivalent (F). (8) Farad (unit of electrical capacity) (f or F). (9) Faraday (unit of electrical quantity) (F). (10) Magnetomotive force (\mathfrak{F}). (11) Degree of freedom (F or f). (12) Free energy, a common usage, but G is used in this book (F). (13) Resonant frequency (f_r). (14) Distribution function (f or F). (15) Focal length of object space (f). (16) Focal length of image space (f'). (17) Hyperfine quantum number (F). (18) Luminous flux (F). (19) Relative humidity (f).

F Layer (F_1 and F_2). That part of the ionosphere with a maxima of ionization; for the F_1 layer in the region 135 to 145 miles altitude and for the F_2 layer in the region 190 to 230 miles altitude. The F_2 layer is the predominant portion of the F layer in the night hemisphere, and is the higher of the two layers (F_1 and F_2) in the F region in the day hemisphere. (See **atmosphere**.)

F-1. U.S. (Rocketdyne Division of North American Aviation) designation for the million pound rocket engine assigned to NAA for development during 1958.

F-108. A projected fighter interceptor expected to develop speeds of Mach 3.

FACTOR OF SAFETY. A design criterion, usually the ratio of the load that would cause failure of a member or structure, to the load that is imposed upon it in service. It may also be used to represent the ratio of breaking to service value of speed, deflection, voltage, temperature, or other stress-producing factor against possible increase in which the factor of safety is provided as a safeguard.

FACTOR OF SAFETY, ULTIMATE. The ratio of the ultimate strength of a structure to the limit load.

FACTOR OF SAFETY, YIELD. The ratio of the yield strength of a structure to the limit load.

FACTOR OF UTILIZATION. A design parameter, the ratio of the allowable stress to the ultimate strength. For cases in which stress is proportional to load, the factor of utilization is the reciprocal of the factor of safety.

FADE. (1) In broadcast terminology, to change signal strength gradually. (2) To undergo partial loss of color of a substance or material on exposure to radiation.

FADE OUT. (1) To fade to a lower signal level. (2) A disruption of radio communications due to severe ionospheric disturbances.

FADING. The fading of radio signals is inherent in the transmission of such signals and at best can only be partially compensated for in the receiver by avc circuits, diversity reception, etc. The compensation may often be made entirely satisfactory if the fading is of the simplest type, but if it is selective, compensation is not always satisfactory. Radio waves going out from the transmitter travel along various paths to the receiver, some of the waves travel along the ground, others are reflected from the ionosphere. In the broadcast band fading is usually caused by signals which have been reflected from the ionosphere combining vectorially with signals which have traveled along the earth (these are called respectively sky wave and ground wave). The sky wave does not return to the earth near the transmitter so there is no fading in this region, and at great distances from the transmitter the ground wave has died out so again there is no fading due to this cause. In the intermediate region both waves may be present and, if the phase of the two signals is such that they cancel, fading results. Since the ionosphere is continually changing, the phase of the reflected sky wave may cause cancellation at one instant and addition of

the signals at the next. Different frequencies travel somewhat different paths in the ionosphere so the time to reach the receiver is different for the different sideband frequencies. Thus one frequency may reach the receiver to add to the ground wave, while another may cancel. This produces what is known as selective fading and the output of the receiver is badly distorted. The other type of fading, in which all portions of the modulated wave are attenuated by the same amount, is called amplitude fading. In radar, the aspect of the target being tracked has influence on the quality of the echo being returned. A signal can be strong or weak according to the aspect, varying as much as 10 to 1. This fading presents problems when the radar design is such as to compare strengths of successive signals for some purpose.

FAHRENHEIT. Temperature scales.

FAIL-SAFE. A provision built into the mechanism of a potentially hazardous piece of equipment which provides that the equipment will remain safe to friendly users even though it fails in its intended purpose. A projectile fuze which is armed with an inertia set-back device so that it remains safe until accelerated in firing would be a fail-safe device. A missile destruct system which operates automatically upon discontinuous of a control signal would be fail-safe.

FAILURE(S). (1) Any physical phenomenon, which prevents a missile from achieving its objective. (2) Any change in an equipment or component thereof, usually due to aging and/or environmental stress, which prevents it from performing the functions for which it was designed.

FAILURE CLASSES. (1) Early Failures: Those failures which occur early in the life of an equipment at a rate in excess of the rate to be expected due to chance. Failures due to inherent weakness built into the equipment during fabrication in excess of inherent design weaknesses. (2) Chance Failures: Failures which occur at a constant rate following removal of early failures. Failures due to inherent weaknesses in the equipment or process design. (3) Wearout Failures: Failures which occur late in the life of an equipment and ultimately are cause for failure of all equipment remaining. Failure due to

weaknesses created in the equipment by its use. (4) Catastrophic Failures: Failures which cause an equipment to become inoperative.

FAILURE CLASSES, PHYSICAL CAUSE.

(1) Design Oversight: Condition correctable by changing design parameters and/or specified materials. (2) Low Safety Factor: Specified use of materials at or near their strength limits. (3) Excessive Variance: Use of materials or combinations of materials whose statistical variability is such that the equipment has a high probability of failure. (4) Production Engineering: Use of manufacturing or assembly techniques which produce unsatisfactory deviations from prototype. (5) Workmanship: Individual variations from specified or normal manufacturing or assembly techniques. (6) Inspection: Failure to detect a defect when methods for detection are available or can be developed. (7) Process Drift: Gradual shift or a processing technique to the point at which one or more parameters are intolerable. (8) Handling and Storage: Subjection of an equipment to non-use conditions in excess of normal or specified conditions. (9) Adjustment or checkout: Use of procedures or operating techniques for adjustment or checkout which causes failure of an equipment or its parts.

FAILURE CLASSES, SEVERITY.

(1) Abortive: One that judgment and experience indicate could result in catastrophic failure of the entire weapon system. (2) Critical: One that judgment and experience indicate could result in failure of the entire weapon system other than catastrophic. (3) Time Limit: One that judgment and experience indicate can become critical or abortive but which has been averted by replacement within a specified time. Time limit failures will only be classified by actual weapons system experience. (4) Non-Critical: One that judgment and experience indicate will not cause failure of the entire weapon system. (5) Associated: One which results from the failure of another interdependent equipment. A failure which judgment and experience indicate would not have occurred if failure of an associated equipment had not occurred.

FAILURE, COMPONENT-COMPENSATING. A malfunction of one component of a

system which nullifies the effect of failure of another component.

FAILURE, COMPONENT-DEPENDENT. A malfunction of a component which is the direct result of the failure of another component.

FAILURE, COMPONENT-INDEPENDENT. A malfunction of a component which does not affect the probability of failure of another component.

FAILURE, COMPONENT-PARTIAL. A malfunction of a component which reduces the normal accuracy of a missile rather than causing its direct and complete failure.

FAILURE MODES. Failure classes.

FAILURE PROBABILITY. A means of calculating the probability of failure of a component, based on the operations of the component and the possibility of a reduced margin of safety:

$$P_f = \frac{P_o P_i + (1 - P_o) P_s}{1 - P_o + P_o P_i}$$

where P_f is the probability of occurrence of a component failure under specified conditions, P_o is the probability of occurrence of a manufacturing error that will cause failure. P_i is the probability of occurrence of an inspection missing a manufacturing error; and P_s is the probability of occurrence of a strength-stress scatterband overlap.

FAILURE RATE. The number of failures experienced by an equipment in a selected period of time; a statistical term important in the theory of reliability. (See also **mean life**.)

FAILURE TERMS. (1) Defect: Any physical property which precludes an equipment's conformance to a specified characteristic. (2) Defective: (a) To contain one or more defects. (b) An equipment which contains one or more defects. (3) Reject: An equipment which has been discovered to be defective and which cannot be made acceptable by further processing. (4) Rework: An equipment which has been discovered to be defective and which can be made acceptable by further processing. (5) Failure: (a) An equipment which contains no defects which adversely affect the function of the equipment

upon completion of fabrication, but which becomes defective after completion; (b) An equipment which is found to be responsible for failure of equipment of which it is a part; (c) The event responsible for an equipment becoming a failure. (6) Malfunction: Synonymous with failure.

FAIRCHILD. A **phototheodolite** used for missile tracking. It was developed by the U.S. Army Signal Corps.

FAIRCHILD FLIGHT ANALYZER. A tracking camera used to track aerodynamic vehicles. It is manually operated by two handlebars fixed to the camera body. The camera is arranged to expose film at regular intervals of angular rotation. Thus, as the camera follows a moving target it records a series of exposures. It has an internal timing system to effect sequential coverage. The camera can be elevated only slightly during tracking, and is intended for level flight tests only.

FAIRING. An auxiliary member or structure on an aerodynamic surface (such as that of a missile) whose primary function is to reduce the aerodynamic drag or to protect the part against aerodynamic forces. Usually it acts to shape outside surfaces in conformance with aerodynamic streamlines.

FALCON (1,2). (GAR-1,2,3,4). A series of supersonic, guided, airborne rockets developed by the Hughes Aircraft Company for the U.S. Air Defense Command. They are launched by fighter aircraft (F-89H, F-89J, F-101B, and F-102). They are powered by Thiokol solid-propellant rockets. GAR-1 and -3 have semiactive pulse radar guidance, GAR-2 and -4 have passive infrared guidance. Their weight is about 100 lb.; their length, 6 ft. 6 in.; and their diameter, 6½ in. They are designed for internal or under-wing installation. (See **missile, guided**.) (See also illustration facing Page 154.)

FALL-AWAY SECTION. Any section of a rocket vehicle that is cast off and falls away from the vehicle during flight.

FALL-BACK. That portion of the material carried into the air by a nuclear explosion which ultimately drops back into the crater formed by an underground or surface burst, or into the water in the immediate vicinity

of the site of the burst in the case of a water shot.

FALL-OUT. A deposit of radioactive material created by a nuclear explosion that has settled out of the air or from contaminated water.

FALL TIME. Time constant.

FALL-WIND. A wind blowing down a mountainside; or any wind having a strong downward component. Fall-winds include the Foehn, mistral, bora, williwaw, etc.

FAR SIDE. The instrument package which so far has reached farthest out into terrestrial space does not belong to a satellite, but to a 4-stage sounding rocket vehicle of Project "Farside." The purpose of this project, which started in November 1956, was to investigate the practicability of a very high altitude sounding rocket, composed of existing hardware. Under contract to the U.S. Air Force Office of Scientific Research, the Aeronic Systems, Inc. developed a 4-stage sounding rocket vehicle, composed of 4 Thiokol **Recruit** rockets as first stage, a single **Recruit** as second stage, 4 Grand Central Rocket Co. rockets now used in the **Asp** sounding rocket as third stage and a single **Asp** rocket as fourth stage. The complete unit was airlifted on a 200 ft. balloon which took it to about 100,000 ft., where the first stage took off vertically through the balloon. In the summer of 1957 the vehicle reached an altitude of approximately 4,000 miles. The exact altitude is not known due to transmitter failure. Although vertical ascent is most expensive in terms of velocity losses due to gravitational pull, the method applied here avoided this disadvantage by lifting the system out of the dense atmosphere and then launching it in a rapid sequence of very high acceleration propulsion periods. The terminal velocity of the vehicle was 25,000 ft/sec. The last stage carried an instrumented package and 4 antennae, weighing 3.5 lb. In spite of its low weight, it carried a **magnetometer**, cosmic ray counter and transmitter, and apparently an **accelerometer** with battery. The test was not conclusive. A preliminary analysis of the data transmitted indicated that the vehicle was subject to decelerations which varied with altitude rather than to a straightforward decrease in deceleration as the square

of the distance, as one would expect in "empty" space at altitudes beyond 1,000 nautical miles. In view of the clouds of trapped particles discovered by Explorer III in certain regions, it may be possible that the Earth, beyond the relevant limits of our known neutral atmosphere, is surrounded by highly conducting and fairly dense atmospheric rings which may resemble or coincide with the Stoermer current rings.

FARAD. A unit of capacitance, abbreviation f or fd. The farad is the capacitance of a **capacitor** (or condenser) which acquires a charge of one coulomb when a steady potential difference of one volt is maintained across its terminals. The microfarad (10^{-6} f) and the micromicrofarad (10^{-12} f) are used as units of capacitance much more often than is the farad.

FASTAX CAMERA. A high-speed motion picture camera used for observation of missiles at launch and for studying vibration phenomena in the laboratory. Frame speeds approach 7500 per sec. Accuracy between frames is measurable to about $\pm 1\%$.

FAST CODE. Timing; slow code.

FATHOM. A nautical unit of linear measure equal to 6 feet.

FATHOMETER. A **sonar** device for measuring the depth of water beneath a ship.

FATIGUE. The phenomenon of the progressive fracture of a metal by means of a crack which develops and spreads under repeated cycles of stress. (See **endurance limit**.)

FATIGUE, ELASTIC. An increase in the **damping** factor of an elastic solid which occurs after a large number of oscillations. If the substance is permitted to rest, recovery takes place and the damping factor returns to its normal value.

FBM (Fleet Ballistic Missile) (Polaris). An intermediate range ship-launched ballistic missile.

FCC. Federal Communications Commission.

FCS. Federal Catalog System.

Fe. Iron.

FEED SYSTEM. Pressure feed system.

FEEDBACK. (1) The transfer of energy from a high to a low level. (2) The transfer of energy from a point nearer the end of a system to a point nearer the input, as for purpose of automatic control. (3) In a magnetic amplifier, a circuit connection by means of which an additional magnetomotive force, which is a function of the output quantity, is used to influence the operating condition.

FEEDBACK FILTER, INVERSE. Filter, inverse feedback.

FEEDBACK, INDUCTIVE. Inductive feedback.

FEEDBACK, INVERSE. A vacuum-tube circuit arrangement in which a voltage is fed back from the plate circuit to the grid circuit; used in radio-frequency circuits to improve the stability, and in audio-frequency circuits to reduce distortion and thus permit greater undistorted power output. Also termed degeneration, negative feedback, and stabilized feedback.

FEEDBACK, NEGATIVE. Feedback which decreases amplification, being 180° out of phase with the input signal.

FEEDBACK, POSITION. A type of feedback in control systems in which position of the controlled device is used as the reference e.g., position of a wing, swivelled engine, radar dish, etc. (See figure.)

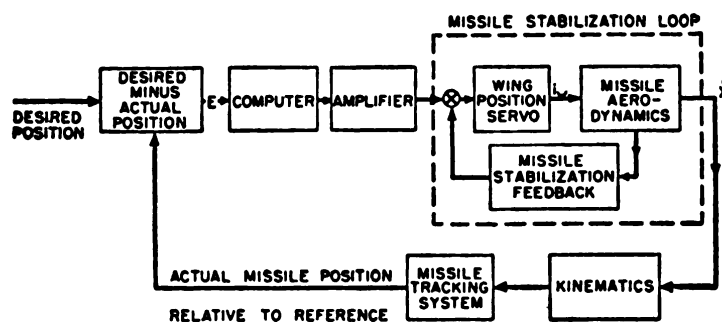
system and compared with the reference signal to obtain an actuating signal which then returns the controlled variable to the desired value.

FEEDBACK, STRUCTURAL. A low frequency oscillation of the airframe structure, caused by feedback (through the airframe or the air) of the structural and rigid body vibrations to servo mechanisms located within the airframe, causing actuation of the aircraft controls in response to the vibrations.

FEEDBACK TESTS, STRUCTURAL. A test to determine the flight control system stability characteristics during structural feedback vibration.

FEEDER. (1) In electrical circuits, the lines running from a main switchboard to branch panels in an installation. (2) In radio circuits, the transmission line from the transmitter to the antenna.

FEELING, THRESHOLD OF SOUND (OR DISCOMFORT, TICKLE, OR PAIN). For a specified signal, the minimum effective sound pressure of that signal which in a specified fraction of the trials will stimulate the ear to a point at which there is the sensation of feeling (or discomfort, tickle, or pain). Characteristics of the signal and the measuring technique should be specified in every case. This threshold is customarily expressed



Missile positioning servo system employing wing position control.

FEEDBACK, POSITIVE. Feedback which increases amplification, being in phase with the original signal. (Contrast with feedback, negative.)

FEEDBACK SIGNAL. In a control system, a signal responsive to the controlled variable. This signal is returned to the input of the

in decibels relative to 0.0002 microbar or to 1 microbar.

FEINT ATTACK. A simulated attack intended to draw ineffective enemy fire.

FELIX. A U.S. Army Air Corp guided bomb developed during World War II. It was

officially designated as the VB-6. It was planned to be used against steel mills, oil refineries and shipyards. It contained a heat-type target seeker.

FERRI DIFFUSER. Diffuser, oswatitsch.

FERRITE(S). The inorganic salts of the formula MFe_2O_4 , where M represents a bivalent metal. Almost all of these materials are magnetic, and cores made of sintered powders find considerable high-frequency application because of the extremely low core losses.

FERROELECTRIC. Some dielectric materials, notably Rochelle salt, potassium dihydrogen phosphate, and barium titanate, exhibit spontaneous polarization and hysteresis between polarization and field. By analogy with ferromagnetic materials, these substances are called ferroelectric.

FERROELECTRIC EFFECT. The phenomenon whereby certain crystals may exhibit a spontaneous dipole moment (which is called ferroelectric by analogy with ferromagnetic—exhibiting a permanent magnetic moment). The effect in the most typical case, barium titanate, seems to be due to a polarization catastrophe, in which the local electric fields due to the polarization itself increase faster than the elastic restoring forces on the ions in the crystal, thereby leading to an asymmetrical shift in ionic positions, and hence to a permanent dipole moment. Ferroelectric crystals often show several Curie points, domain structure hysteresis, etc., much as do ferromagnetic crystals.

FEUERLILIE. In German, "Fire Lily." The name referred to a family of antiaircraft guided missiles. The missiles of this group which were actually fired were used for investigating problems of aerodynamics and ballistics, by the Hermann Goering Research Institute at Volkenrode, Germany. The Feuerlilie 25 was made by Rheinmetall-Borsig Company. The missile was a solid propellant rocket approximately $6\frac{1}{2}$ feet long and 265 pounds overall weight. The missile had a 10 inch diameter and a monoplane wing of $3\frac{1}{2}$ feet span and 40 degrees sweepback. The missile was able to attain 720 feet per second velocity with a 1000 pound thrust rocket motor burning for six seconds. The Feuerli-

lie 55 was another small antiaircraft rocket. Initially the 55 was a solid propellant type which was later changed to an alcohol-LOX version. Weights of the two versions of the F55 were 1040 and 1443 pounds respectively. Overall length was 15 feet 9 inches with a diameter of just over a foot. The missile had a $7\frac{1}{2}$ foot wing span and attained a velocity of 1460 feet per second with a maximum range of approximately five miles. Maximum altitude was approximately 30,000 feet with booster assist or 16,000 feet without booster. Thrust of the solid propellant version was 8800 pounds with 6 seconds burning time. Thrust of the liquid propellant type was 2200 pounds for 25 seconds.

FEUERWERK. A German AA missile developed during World War II by the Bruenner Waffenwerke.

FFAR. Forward-Firing Aerial Rocket.

FIDELITY. The degree with which a system, or a portion of a system, accurately reproduces at its output the essential characteristics of the signal which is impressed upon its input.

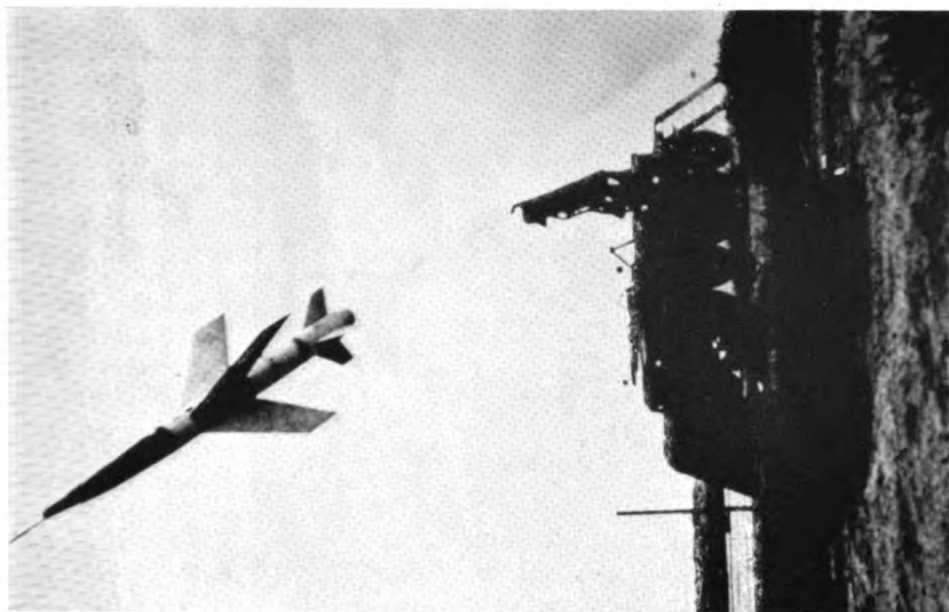
FIDUCIAL LINE. An accurately located and known reference line used for alignment of the airframe or guidance system. It is frequently a line to which gyroscope axes are referenced.

FIDUCIAL MARKS. On measuring instruments, marks used as the measurement reference and as indications of units for measurements. For example, in photogrammetry, index marks are etched in the camera optics to form images on the negative which can then be used to define points appearing on the photograph.

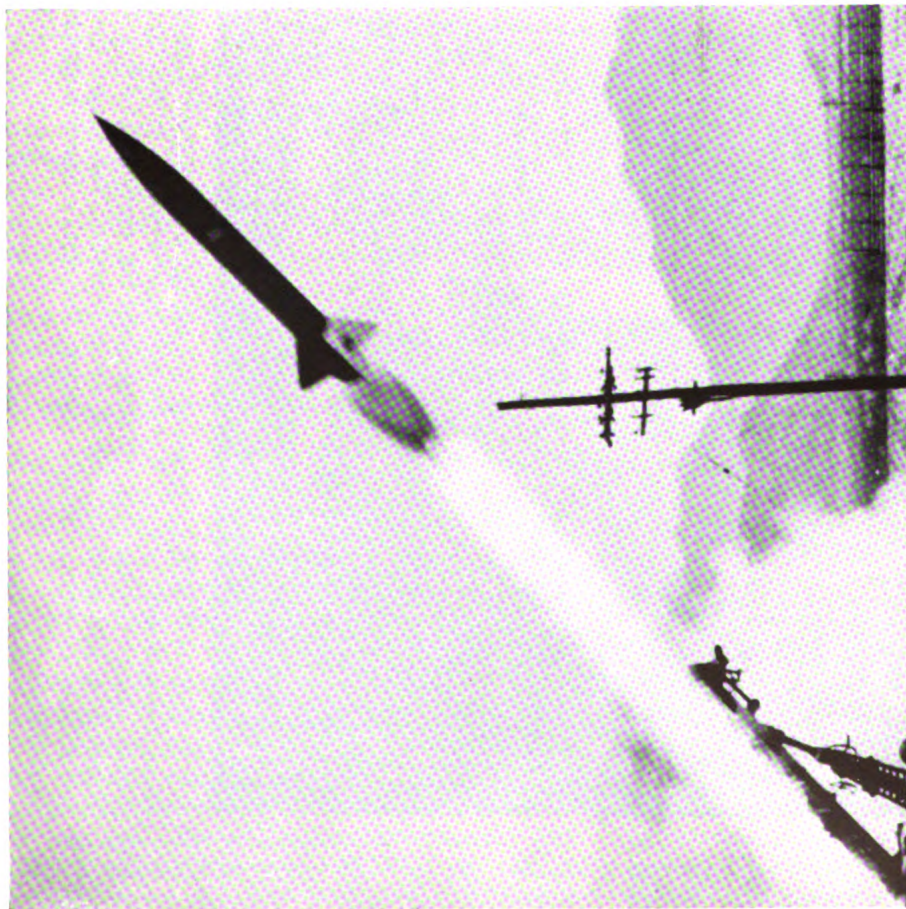
FIELD. (1) A region or space in which a phenomenon occurs. (2) A field of force. (3) An electromagnetic field. (4) A sound field. (5) A field of view. (6) In electric motors and generators, the field is the part of the machine which furnishes the magnetic flux which reacts with the armature to produce the desired machine action. The field may be the fixed part of the machine or, as is usually the case in synchronous motors and generators, the field may be the rotating part of the machine. (7) The energy radiated from an antenna system of a radio trans-



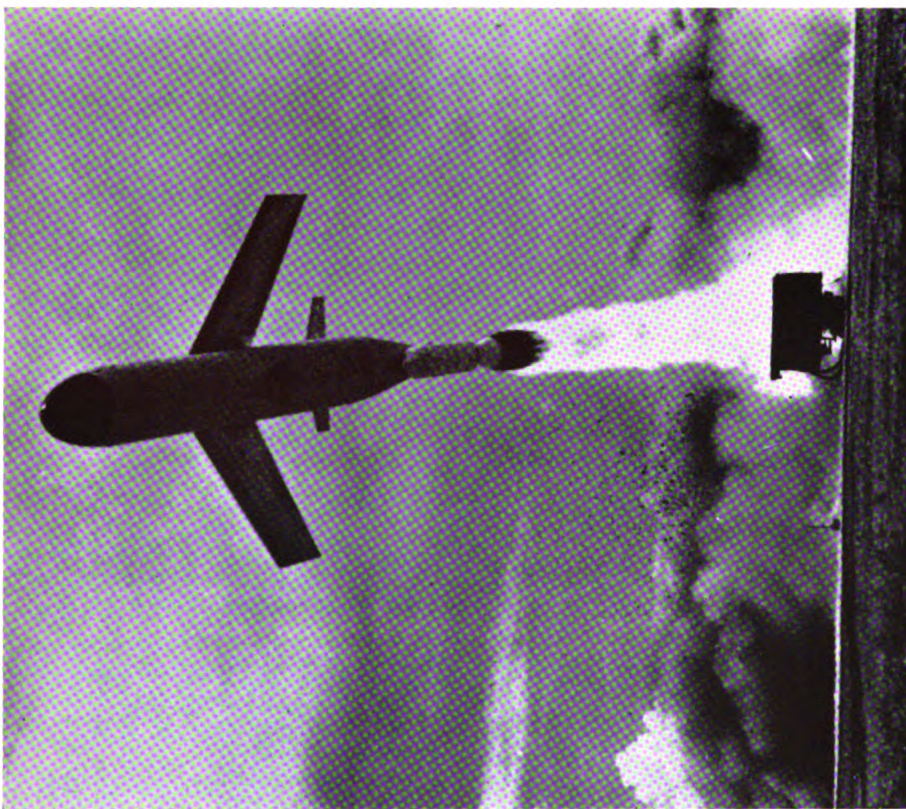
A U.S. Army JUPITER C three-stage test missile blasts off from Cape Canaveral, Florida, on an August 8, 1957 test of a re-entry nose cone developed by the Army Ballistic Missile Agency, Huntsville, Alabama. The successful test proved that Army missile experts had overcome a hurdle which balked missile scientists for years; the problem of air-friction heating when a missile re-enters the earth's heavy atmosphere. (*U.S. Army Photograph*)



The LA CROSSE, the Army's surface-to-surface guided missile immediately after launching at the Army Ordnance Proving Ground. January 16, 1957. (*U.S. Army Photograph*)



The U.S. Army LITTLE JOHN rocket is fired from launcher during test held at the Small Missile Range, White Sands Proving Ground. August 1, 1957. (U.S. Army Photograph)



The Martin TM-76 MATADOR, latest version of the TM-61 presently in operational use overseas, has added a new capability to its primary objective of target destruction. A recovery kit, replacing the section of the missile containing the warhead, has been installed, permitting recovery and reuse of the missile. The MATADOR is controlled in recoverable flight by an MSQ radar command system. Initial impetus for MATADOR take-off is furnished by a booster bottle containing a solid rocket propellant, which is jettisoned soon after the missile is airborne. (U.S. Air Force Photograph)

mitter. This field is electromagnetic, consisting of both an electric and magnetic component. It is the interaction of these fields with the receiving antenna which causes the signal voltage to be induced in the antenna, and hence introduced into the main receiver-circuit.

FIELD COIL. The coil used to provide the magnetizing force in motors, generators, electrodynamic loudspeakers, etc.

FIELD, ELECTRIC. The attraction (or repulsion) exerted by one electric charge on another can be described quantitatively in terms of the electric field produced by the first charge. By definition, the field at any point is the force (a vector, having magnitude and direction) that would be exerted on a unit positive test charge placed at that point. Hence an electric field is a specific type of force field. The path that would be followed by an inertia-less test particle is called a "line of force." It follows from the **Coulomb law** that the field of a point charge in free space has the magnitude

$$E = \frac{q}{\epsilon_0 r^2}$$

where q is the charge, ϵ_0 is the **permittivity**, r is the distance from the charge, and unrationalized units are employed.

FIELD OF FORCE. Electric charges exert force upon other electric charges, magnets exert forces upon other magnets, matter exerts gravitational force upon other matter. All these action-at-a-distance phenomena are conveniently described in terms of the "force field" set up by a source. The force exerted on a unit test-particle (unit charge, unit pole, unit mass) is a vector function of position of the test-particle. That is, the force on a unit test-particle has a definite magnitude and direction for each possible location of the test-particle. The totality of these force vectors, or the vector function of position, is called a "field of force." Any path that would be followed by an inertia-less test-particle in a force field is called a "line of force." It is convenient to decide arbitrarily how close together possible lines of force are independent, so that there will be a finite number of lines, and the concept can be made quantitative. Conventionally a unit source radiates 4π lines, or one per unit solid angle

in unrationalized systems, and a single line ($1/4\pi$ per unit solid angle) in rationalized systems.

FIELD OF VIEW. The area or solid angle visible through an optical instrument; sometimes similarly applied to a radar.

FIELD STRENGTH. The strength of a field is its magnitude. Thus an electric field has a strength (volts per meter) at a given point, as well as a direction; its strength is, therefore, the magnitude of its **electric field vector**, **E**. (See **field of force**.)

FIELD SUPPORT EQUIPMENT (FSE). That portion of the unit mission equipment for T/O units which permits their operations from a "bare strip."

FIELDISTOR. A **transistor** which utilizes an external electric field for the control of mobile carriers in the **semiconductors**.

FIGURE OF MERIT. (1) General term for various graphical relationships which summarizes certain desirable features of amplifying devices. For a magnetic amplifier, the figure of merit has been defined specifically as the ratio of power amplification of a given control winding to the response time of the magnetic amplifier, under specified control circuit conditions. (2) The current required to produce one division deflection (usually 1 mm on a scale at a distance of 1 m) of a galvanometer. (3) Any quantity which expresses quantitatively the performance of a measuring device, as a radar receiver, or crystal detector.

FILAMENT. The resistive element in a **thermionic tube** through which current is passed to provide the temperature required for **thermionic emission**. The surface of the filament may supply the emission, or the filament may be employed as a heater for an indirectly-heated cathode.

FILAMENT VOLTAGE. The voltage between the terminals of a **filament**, especially in a vacuum tube.

FILLET. A filling material applied at a sharp angled juncture of an airframe for the purpose of smoothing the air flow. Fillets may be made of metal, wood, plastic or other material. (See also **fairing**.)

FILM COOLING. In propulsion, a system of cooling liquid-propellant rocket engines in which one of the propellants is introduced into the motor chamber at critical points such as the throat, through holes bored in the chamber walls. Although this fuel ignites inside the chamber, the initial effect upon the chamber walls is cooling due to the evaporation; the amount of cooling corresponds roughly to the latent heat of evaporation. (See also **cooling**.)

FILM THEORY OR BOUNDARY LAYER THEORY. The film theory as applied to heat or mass transfer has to do with the analysis of the way in which material or heat is transferred across a phase boundary where one or both of the phases may be flowing fluids. Examples of such a transfer would be heat flowing from a pipe to water moving inside, or water vapor passing from a wet surface into an air stream flowing over it. Any study of such processes must be concerned primarily with the major resistance to the flow. It is known that transfer by convection (heat) or mixing (mass) is very much faster than by conduction (heat) or diffusion (mass). If any part of the process involves conduction or diffusion, then this part will undoubtedly offer the greatest resistance to the transfer and hence will be the controlling variable.

Even though the fluid be moving past the surface in a turbulent manner, there will still be, next to the surface, a relatively stagnant *film* of the fluid. Through this film the heat or mass must pass, respectively, by conduction or by diffusion. Calculations involving transfer of heat or mass into a flowing stream are mainly concerned with the effective thickness and the properties of the film. Methods of increasing the rate of transfer are usually based on changes designed to reduce the film thickness or to change the properties of the fluid and hence increase the rate of transfer. Increasing the turbulence of the fluid tends to scrape off the film, thereby making it thinner; and raising the temperature (for liquids) lowers the viscosity of the film and makes it more easily rubbed away by the flowing fluid. Also, raising the temperature increases the rate of diffusion, and usually increases the heat conductance.

The actual film thickness is seldom known, but the way in which various factors (such as

the viscosity, velocity, density, etc., of the fluid) affect it are often known, so that experimentally determined values for the rate of transfer under one set of conditions can usually be used to calculate the rate under a different set of conditions.

FILTER. (1) A device used to remove solids from liquids. It may be in the form of a metal screen, fibrous mass, porous ceramic cup, or mass of fine particles. (2) In electronics, a network containing lumped circuit elements used to select or reject signals in predetermined frequency bands. In radio power supplies, a combination of condensers and chokes or resistors is called a "filter," it serves to pass direct current, while preventing the passage of pulsating direct current. The most familiar type of filter consists of a network of a number of lumped resistances, capacitances and inductances with constant values. (See Figure 1.) An "RC filter" is a

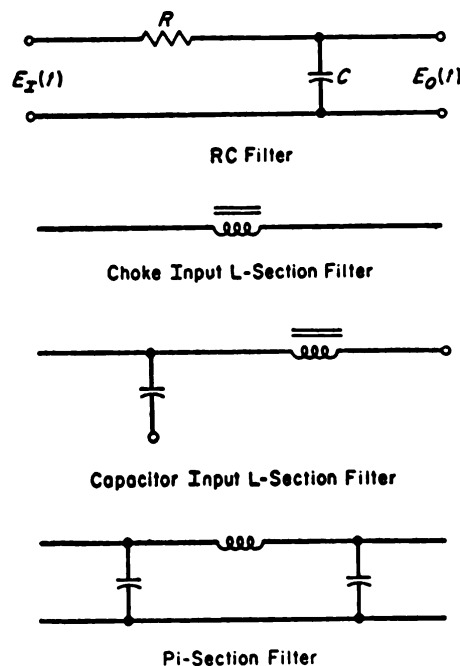


Fig. 1. Typical electronic filter circuits.

filter consisting of a resistor and a capacitor. A choke input L-section filter is used to give a good regulation. A capacitor input L-section filter gives a higher average output voltage and is good for low current applications. A pi-section filter is good for high voltages and low currents, and is a common type used in power supplies. All three of these latter are called L-C filters (for inductance-capacitance).

Such circuits are used as band-pass filters, low-pass filters, high-pass filters, band elimination filters, or ripple filters. (See Figure 2.) (3) A material used in an optical system

FILTER, CHOKE-INPUT. A power-supply wave filter in which the first filter-element is a series choke coil. For best operation the magnitude of the inductance (henries) must

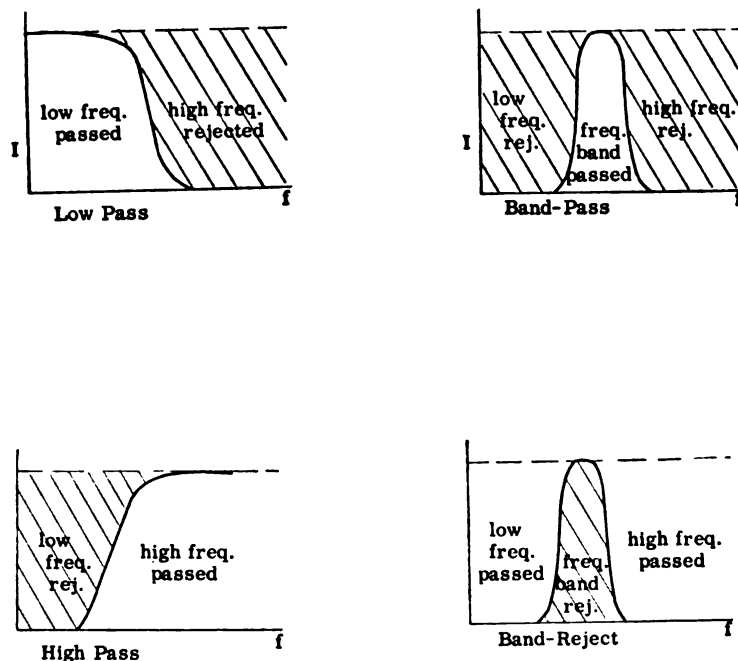


Fig. 2. Characteristic curves for filters.

to absorb a portion of the spectrum (i.e., to exclude a certain color of light).

FILTER, ACTIVE. A filter used for smoothing data. The time delay and/or phase lag introduced by such a low pass filter is cancelled by use of an identical "reciprocal" filter in the feedback circuit of the associated amplifier.

FILTER, BAND-ELIMINATION. A wave filter whose transducer gain is very low over a certain band of frequencies.

FILTER, BAND-PASS. A network (electrical, mechanical or acoustical) which passes a band of frequencies between two particular frequencies. The geometrical mean is equal to the geometrical midfrequency of the pass band.

FILTER, BAND-REJECTION. A network (electrical, mechanical or acoustical) which rejects a band of frequencies between two particular frequencies. The geometrical mean is equal to the geometrical midfrequency of the reject band.

be made larger than the magnitude of the load resistance (ohms) divided by 1100.

FILTER, CRYSTAL. Crystal filter.

FILTER, FREQUENCY. A wave filter (see **filter, wave**) designed to select or pass certain bands of frequencies with low attenuation, and cause very high attenuation to other frequencies. They are among the most important components of most communications systems. In the common radio receiver, filters are used to smooth out the pulsating direct current from the rectifier to give a steady output of the power supply. Telephone carrier circuits are possible because of filters which are used to separate the various channels, and route the signals to the proper paths. The ordinary tuned or resonant circuit might be regarded as a special form of filter, but is not commonly considered as such, since it does not have a flat pass-band.

FILTER, HIGH-PASS. An electrical wave filter having a single transmission band extending from some critical or cutoff frequency, not zero, up to infinite frequency. The value

of the components may be selected as follows:

$$L = \frac{R}{4\pi f_c} \quad \text{and} \quad C = \frac{1}{4\pi f_c R}$$

The cutoff frequency is:

$$f_c = \frac{1}{4\pi\sqrt{LC}}$$

where L is inductance, in henrys, C is capacitance, in farads, and R is load or terminating resistance, in ohms (R is approximately the same value as the input or source resistor).

FILTER, INVERSE FEEDBACK. A resonance bridge circuit used at the output of a high selectivity amplifier, such as an oscillator or wave analyzer. Impedance is adjusted so that the feedback output is zero for the resonant frequency, but increases rapidly as frequency departs from this value.

FILTER, LOW-PASS. An electrical wave filter having a single transmission band extending from zero frequency up to some critical or cutoff frequency, not infinite. The value of the components may be selected as follows:

$$L = \frac{R}{\pi f_c} \quad \text{and} \quad C = \frac{1}{\pi f_c R}$$

The cutoff frequency is:

$$f_c = \frac{1}{\pi\sqrt{LC}}$$

where L is inductance, in henrys, C is capacitance, in farads, and R is load or terminating resistance, in ohms.

FILTER, MECHANICAL. Mechanical filter.

FILTER, NOTCHING. (1) A filter employed in a television transmitter to provide **attenuation** at the low-frequency edge of the channel to prevent possible interference with the sound channel of the lower adjacent channel. (2) Any band-rejection filter which produces a sharp "notch" in the transfer characteristic of a system.

FILTER, OCTAVE. A band-pass filter which permits the passage of a range of frequencies from a lower limit to twice this value.

FILTER, STRUCTURAL. Structural filter.

FILTER, WAVE. A transducer or network for separating waves on the basis of their frequency. It introduces relatively small insertion loss to waves in one or more frequency bands, and relatively large insertion loss to waves of other frequencies.

FIN. A fixed airfoil attached to an airframe, such as that of an aircraft or missile, to provide directional stability.

FIN MISALIGNMENT. The condition of a rocket in which the restoring moment is zero when the yaw of the axis is not zero.

FINAL MASS. The mass of a rocket after its propellants are consumed.

FIN-STABILIZATION. The use of air vanes at the rear of an air vehicle to provide directional stability by keeping the center of pressure behind the center of gravity. The fins operate according to the arrow feather principle, and as in the case of the arrow, fin-stabilizing is effective only in the earth's atmosphere, where a restoring force can result from wind action on the fins. Fin-stabilizing gives a characteristic oscillatory recovery characteristic. Its great advantage is that the fins can also be used for maneuver by the addition of movable surfaces.

FIN-STABILIZED PROJECTILE. Any projectile, as a rocket or missile, steadied in flight by fins.

FINENESS RATIO. In aerodynamics, the ratio of the length to the maximum diameter of a streamlined body. (See **slenderness ratio**.)

FINSEN. A practical unit of **erythema flux** density (intensity of irradiation). It is equal to one unit of erythema flux per square centimeter.

FIRE. To launch a missile.

FIRE CONTROL. (1) A means of controlling fire power of a gun. A fire control system usually consists of a gun director, a computer and the gun on its trainable and elevatable mount. The gun director tracks the target. The computer establishes predicted future position of the target. The gun is directed according to the output of the computer. (2) The term is sometimes ap-

plied to missile guidance when exercised outside the missile.

FIREBALL. The luminous sphere which begins to form a few millionths of a second after a burst of a nuclear warhead.

FIREBEE. A target drone made by Ryan Aeronautical Company. It is powered by a Fairchild J-44 turbojet with rocket boost. It is used by the Air Force for Falcon missile target practice.

FIREBIRD. A large air-to-air missile produced by the Ryan Aeronautical Company. Its official designation was AAM-A-1. The missile's dimensions are: 10 feet in length (including booster), 6 inches in diameter, and 3 feet in wing span. The missile's four rectangular swept-back wings at mid-body, and four tail fins in line with the wings were arranged in cruciform, but the missile flew in an "X" orientation rather than a "+" (with the wings horizontal and vertical). Control by the mother aircraft was by radio until within sensing range of a terminal homer. Power was a bi-propellant liquid fuel motor. It was first announced as a project in 1949. The first firing was at Holloman Air Force Base, New Mexico in 1950.

FIREFLASH. A British (Fairey Aviation Company Ltd.), air-to-air supersonic beam-rider missile. Its dimensions are: 90 inches in length, 28 inches in wingspan in cruciform configuration. It uses two cordite boosters and a solid propellant rocket for power.

FIRESTREAK. A British air-to-air solid propellant rocket missile produced by De Havilland Propeller Ltd. It was to be an infrared seeker according to British announcements made in April, 1957. At that time it was scheduled for operational status in the Royal Air Force at the end of 1958. Its conical nose was designed to be octagonal in order to provide non-distorting glass "viewing panels."

FIRING. (1) The initiation of combustion, and hence the initiation of the operation of any device operating on a combustion process, such as the launching of a missile or rocket ship. (2) In a magnetic amplifier, the transition from the unsaturated to the saturated state of the saturable reactor during the con-

ducting or gating alternation. Firing is also used as an adjective modifying phase or time to designate when the firing occurs. (3) The initiation of discharge in a gas discharge tube.

FIRING ANGLE. Gate angle.

FIRING, BLOW-DOWN. Simulated missile thrust engine system operation with non-combustible fuel combinations.

FIRING, FLIGHT. Hot firing of missile engine during flight.

FIRING, HOT. Missile thrust engine operation with combustible fuel.

FIRING KEY. A device, either electrical or mechanical, which when actuated will initiate an action to launch a missile.

FIRING, MOCK. A test that stimulates a complete flight test operation with the exception of firing.

FIRING TABLES. For ballistic missiles, precomputed trajectories for given launch points and targets.

FIRING TEST(S), CAPTIVE. Missile tests which are conducted with the engine firing and the missile secured to the test stand, to evaluate and develop the missile system.

FIRING TEST, FLIGHT-READINESS. Short duration hot firing test of a flight missile secured to a test stand at test field. This test is run to checkout the missile for flight status. The engines are started and brought up to full thrust.

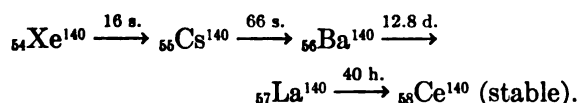
FIRST LINE LIFE. A U.S. Air Force term referring to the period during which an aircraft or missile can be expected (or has), existed as a primary operational type. It is the period from first operational use to obsolescence. For planning purposes, the first line life of Air Force missiles has been considered to be five years.

FIRST MOTION. In guided missile range terminology, the first indication of motion of the missile or test vehicle from its launcher. It is synonymous with **take-off** for aerodynamically supported vehicles and **lift-off** for vertically launched ballistic missiles. Some systems of range timing are re-cycled to read zero from first motion.

FIRST POINT OF ARIES. The vernal equinox.

FISHBONE ANTENNA. Antenna, fishbone.

FISSION CHAIN OR FISSION DECAY CHAIN. The successive β -decays starting with a fission product and ending in a stable nucleus of the same mass number. For example:



FISSION, NUCLEAR. The division of a heavy nucleus into two major parts. For the heaviest nuclei the reaction is highly exothermic, the release of energy being about 170 Mev per fission. A well-known example is the fission of the compound nucleus formed when U^{235} captures a slow neutron. Other examples are the fissions of U^{233} and Pu^{239} by the capture of slow neutrons. The approximate equality of the fission fragments distinguishes fission from such processes as **spallation**, in which relatively small fragments are ejected, leaving only one large residual nucleus. Fission has been induced by neutrons, charged particles, and photons. When induced by photons, it is called **photo-fission**. Spontaneous fission is fission that occurs without particles or photons entering the nucleus from the outside. For this rare mode of radioactive decay which occurs only in the heaviest elements, the half-lives for decay are, without exception, very long. Ternary fission is the splitting of a nucleus into three nuclear fragments; there is disagreement as to whether this term should be used for the often-observed type of fission in which a small charged nuclear fragment (such as a proton, alpha particle, tritium, or Li^8 nucleus) is emitted during the process of splitting into two massive fragments, or whether it should be reserved for splitting into three massive fragments, a process that has not been observed conclusively.

FISSION PRODUCTS. Elements and/or particles created by nuclear fission. These may consist of more than 40 different radioactive elements: barium, iodine, cerium, arsenic, silver, tin, cadmium, and others.

FITTING. A device to connect pipes, tubes and other plumbing into a unit of installation.

A-N fittings (i.e., Army-Navy fittings) are those most frequently encountered in military plumbing. These replaced the old AC (Air Corps) fittings which were the standard before World War II. The A-N types are distinguishable from the AC types in that the AC had no shoulder between the end of the tube threads and the flare cone. There is also an MS (Military Standard) fitting which is used mostly for flareless fittings. (See **ermeto fitting**.) Fittings are usually made of aluminum alloy, steel, and bronze or brass. All varieties of fittings are made of aluminum but only certain types are made of brass or bronze. Visual identification of the type of material in a fitting is provided by the color of the exterior. Brass or bronze are left unpainted, aluminum alloy fittings are dyed blue, and steel fittings are colored black.

FIX. In navigation, the location of an observer determined by intersecting directional lines taken from (two or more) objects of known position.

FIXED-AREA EXHAUST NOZZLE. On a jet engine, an exhaust nozzle exit opening which remains constant in area. (Cf. **variable-area exhaust nozzle**.)

FIXED ERROR. A term used in precise alignments, the offset between a preset position and the observed median value.

FLAC. The shortened name of the Florida Automatic Computer at the Air Force Missile Test Center, Florida. FLAC is a high speed, large capacity, digital computer with a circuit philosophy resembling the Bureau of Standard's SEAC. The machine has a basic pulse repetition rate of one megacycle per second and handles numbers in a binary scale of notation to a precision of 44 digits (13 decimal digits with sign). It originally used a 512 word mercury delay line memory; this was expanded to 4096 words in early 1957. With the increased memory, it performs approximately 2000 operations per second. Read-in and read-out is by punched paper tape, magnetic tape or magnetic wire. Paper tape readers work 600 characters per second. Magnetic tapes are available with reading rates of 3000 characters per second.

FLAGPOLE ANTENNA. Antenna, flagpole.

FLAK. German terminology for anti-aircraft guns and their bursting projectiles.

FLAME. A reaction or reaction-product, partly or entirely gaseous, which yields heat and more or less light, as the result of a chemical reaction, commonly oxidation.

FLAME ATTENUATION. A phenomenon occurring when microwave energy is directed through the exhaust gases from rocket or ramjet engines. The attenuation varies with the microwave frequency, the direction and power of the beam, the characteristics of the exhaust flow, the propellant, combustion efficiency, and altitude.

FLAME BUCKET. In liquid rocket engine test stands, the structure used to deflect the engine exhaust gases (often water-cooled).

FLAME DEFLECTOR. A device for deflecting the exhaust flame of a rocket motor away from structural areas it might damage.

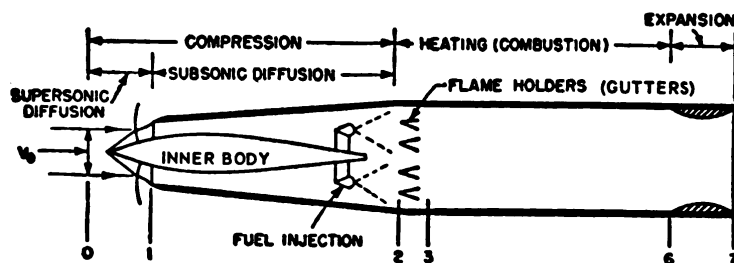
FLAME HOLDER. A device inserted in the combustor of an air-breathing engine designed to stabilize a flame. (See Figure.) Phys-

FLAMMABILITY. Readiness to ignite and burn, a term applied to materials not intended for use as fuel. It corresponds to the flash point of fuels. Flammability is determined by exposing a sample of the material under test to a standard flame. The duration of any flame and/or the extent of the charred area resulting is the measure of flammability.

FLANGE, CHOKE. A low-loss, waveguide coupling. It consists of a half-wavelength, low-impedance line inserted in series with the waveguide at the joint.

FLAP. A hinged airfoil at the rear of a surface, which by its adjustment increases the camber of the surface, and so gives increased lift or attitude control to an air vehicle. In some cases it also increases the chord length when extended.

FLAP, DIVE. A flap used to increase drag while maintaining or improving the stability of a diving air vehicle. It is often used in



ically, a flame holder is a metal grid or shield of some sort punctured with a variety of sharp-angled holes (usually not round). Burning propellants tend to linger in the corners of these holes and this insures continued ignition of the injected fuel throughout the operating cycle. Flame holders are necessary to prevent "blow out" of the burning fuel by the air rushing through the combustion chamber.

FLAME OUT. Acceleration blowout.

FLAME PROPAGATION. In a jet engine, the process by which the flame is caused to continue burning in a combustion chamber after the initial ignition.

FLAME SHIELD. Sandwich type rigid insulation that protects the attachment frames, thrust mount, and load struts from heat during firing.

symmetrical pairs protruding from the fuselage.

FLAP, SPLIT. A hinged plate forming the rear upper or lower portion of an airfoil. The lower portion may be deflected downward to give increased lift and drag; the upper portion may be raised over a portion of the wing for the purpose of lateral control.

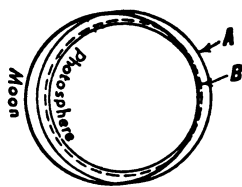
FLAPERONS. Airfoil surfaces combining the braking and lift effects of flaps, and the attitude (i.e., roll) controlling ability of ailerons.

FLASH DEPRESSANT. A compound added to solid propellants (usually those of granular type) to reduce the intensity of the exhaust flame.

FLASH POINT. The lowest temperature at which a substance, when heated under spec-

ified test conditions yields a vapor which ignites on contact with a specified flame or spark. The flash so produced is defined as momentary or "for x seconds" according to the test used.

FLASH SPECTRUM. At the instant of second or third contact during a total solar



Flash spectrum.

eclipse the edge of the moon is tangent to the photosphere of the sun as shown in the figure. With the photosphere covered, the highly heated atmosphere of the sun, known as the reversing layer and the chromosphere, flashes into view. With the photosphere covered the continuous spectrum of the sun is cut off and the bright-line spectrum radiated by the atmosphere may be observed.

If a photograph is taken with an objective prism at the instant of second or third contact, a series of curved images of the atmosphere of the sun will be obtained, each in one particular radiation. As indicated in the figure, radiations due to elements at the highest levels, as at A, will give longer curves than the radiations due to elements at lower levels such as B. Such a bright-line spectrum is referred to as a flash spectrum, since it is only visible for a few seconds at the instants of the contacts.

FLEMING'S RULES. Rules for relating direction of the motion of a conductor through a magnetic field, the direction of the lines of force, and the direction of current flow in the conductor. Rule for Generators: Hold thumb, index finger, and the middle finger of the right hand so that they are at right angles with each other. If the thumb is pointed in the direction of motion of the conductor, the index finger points in the direction of the lines of force, and the middle finger points in the direction of the induced e.m.f. through the conductor. Rule for Motors: Holding the fingers of the left hand as above, the thumb points in the direction of motion of the conductor, the index finger, in the direction of the lines of force, and the middle finger in the direction of current flow through the conductor.

FLEXURE. A state of curvature or bending, or the movement resulting in that state.

Thus, flexure denotes the relative motion which occurs between structural parts of a missile, aircraft or ship. When flexure is caused by aerodynamic forces the effect is termed **aeroelastic**. Flexure adversely affects the use of such a structure as a reference for direction-sensing devices.

FLICKER CONTROL. Radio control of an aircraft, missile, etc. in which the control surfaces are deflected to their fullest degree with any motion of the remote control. (Cf. **proportional control** and see **bang-bang control**.)

FLIGHT. (1) The condition of a vehicle above the surface of the earth when supported by momentum or aerodynamic forces. (2) The smallest Air Force organization possessing both launch and guidance capability.

FLIGHT CHARACTERISTIC. A characteristic exhibited by an aircraft, rocket missile or the like in flight, such as a tendency to stall or to yaw, an ability to remain stable at certain speeds, etc.

FLIGHT CONTROL SYSTEM. Control system, flight.

FLIGHT MECHANICS OF SPACE VEHICLES. For those space vehicles which are destined to occupy orbits, flight mechanics include the analysis of trajectories for earth-to-orbit ascent, from vertical ascent to horizontal flight at circular or elliptical orbital velocity. The three principal methods of ascent are discussed under **elliptic ascent**, **ballistic ascent**, and **powered-all-the-way (PAW) ascent**. (See figure under **elliptic ascent**.)

FLIGHT OPERATOR. A person who controls the flight of an air vehicle.

FLIGHT PATH (TRAJECTORY). The path of the center of gravity of a missile, usually with reference to the earth.

FLIGHT READINESS FIRING. A U.S. Air Force term for a captive firing of a missile, including a check-out of all its components and systems to prove it ready for actual launching.

FLIGHT TABLE. A rate, roll, and/or tilt table used for gyroscope testing. It is used to check gyro position and/or rate outputs.

FLIGHT TEST. Tests conducted to determine system operational characteristics, re-

liability, and sequencing while the missile is in flight.

FLIGHT TEST, CERTIFICATION. A propulsion test to prove the capability of the component to function properly in a minimal flight environment (temperature and vibration). Less stringent than for flight qualification tests.

FLIGHT TEST, QUALIFICATION. A propulsion component test to prove the capability of the component to function properly under stringent flight and ground environmental conditions for use in the flight article.

FLIGHT VEHICLE. Flying vehicle.

FLIP-FLOP CIRCUIT. A circuit with one stable and one quasi stable state. A single trigger is required to produce a complete cycle.

FLOATING DECIMAL POINT. In computers, a system of determining the position of the decimal point of numbers by means of an indicator appearing at the end of the recorded number, no decimal at all occurring in the number itself. The indicator for IBM type machines consists of the last two digits of the number and these digits indicate how many places the decimal point is to be moved. In the tabulation of numbers the decimal point will always appear in the same position or may be omitted altogether. The floating decimal notation is necessary to avoid complication in the tabulating machinery. The following example is typical although other variations exist:

-.0000000 -05 = -0.00000
 .1111111 04 = +1111.111
 -.9990000 03 = -999.
 .2222222 -01 = +0.2222222

FLOP-OVER CIRCUIT. Trigger circuit.

FLOTATION (GYRO WHEEL). In hermetically sealed integrating gyroscopes, a means of relieving the gimbal bearing load by floating the enclosed wheel assembly in a liquid. For a single axis gyroscope this liquid may be used for damping by controlling the viscosity.

FLOW DIAGRAM. A graphical representation of a sequence of operations.

FLOWMETER. An instrument used to measure the flow rate (quantity per unit time) of a moving fluid. In missile applications the rate of fuel flow is an important factor in the functioning of the propulsive system. Because highly corrosive fluids, or because of extreme temperature situations (e.g., liquid oxygen), a simple mechanical device is not often usable for flow rates. Electromagnetic flowmeters using the Faraday effect between the moving fluid and a magnetic field to produce an electromotive force proportional to the average flow velocity have been developed. These are difficult to apply since the Faraday effect signal is of the order of millivolts. Polarization voltages, electrolytic battery films, potential differences of eddy currents or stray sources cause the electromagnetic flowmeter to be difficult to calibrate. They are widely used, however, as are other indirect indicators.

FLOW, INVISCID. Fluid flow neglecting the effects of viscosity.

FLOW, LAMINAR. A type of streamline flow in which fluid in thin parallel layers tends to maintain uniform velocity. The term usually is applied to the flow of a viscous fluid near solid boundaries, when the flow is not turbulent.

FLOW, SEPARATION OF. The flow of a slightly viscous fluid past a solid body closely resembles that of an inviscid fluid so long as the thin layer of retarded fluid near the wall is not brought to rest by the pressure gradients of the flow. If it is brought to rest, the whole flow separates from the surface and the direction of flow is reversed downstream of the position of flow separation.

FLOW, STEADY. Flow in which the flow velocity at a point fixed with respect to the coordinates is independent of time. If the flow is turbulent, a flow in which the mean values are independent of time. Many common flows may be made steady by a suitable choice of the coordinates.

FLOW, STREAMLINED. In a fluid flow, the path of particles originating at a common point. Except very near a body and in its wake, a flow streamline does not change direction with time.

FLOW, TURBULENT. Flow in which the fluid velocity at a fixed point fluctuates with

time in a nearly random way. The motion is essentially rotational, and is characterized by rates of momentum and mass transfer considerably larger than in the corresponding laminar flow. (See **flow, laminar**.)

FLOX. Fluorine plus liquid oxygen.

FLUCTUATION NOISE. Random noise which has a uniform energy versus frequency distribution. Examples are **thermal noise** and **shot noise**.

FLUID FLOW. Just as there are many types of fluids, so there are, partly as a result, many types of fluid flow. *Uniform flow* is steady in time, or the same at all points in space. *Steady flow* is flow of which the velocity at a point fixed with respect to a fixed system of coordinates is independent of time. Many common types of flow can be made steady by a suitable choice of coordinates. *Rotational flow* has appreciable vorticity, and cannot be described mathematically by a velocity potential function. *Turbulent flow* is flow in which the fluid velocity at a fixed point fluctuates with time in a nearly random way. The motion is essentially rotational, and is characterized by rates of momentum and mass transfer considerably larger than in the corresponding laminar flow. *Laminar flow* is flow in which the mass of fluid may be considered as advancing in separate laminae (sheets) with simple shear existing at the surface of contact of laminae should there be any difference in mean speed of the separate laminae. If turbulence exists, its effect is confined to a lamina, and there is no exchange of momentum between laminae. *Streamline flow* is flow in which fluid particles move along the streamlines. This motion is characteristic of viscous flow at low **Reynolds numbers** or of inviscid, irrotational flow. *Secondary flow* is a less rigorously defined term than many of the foregoing types of flow. The flow in pipes and channels is frequently found to possess components at right angles to the axis. These components which take the form of diffuse vortices with axes parallel to the main flow form the secondary flow. Three types may be mentioned: (i) Secondary flow in curved pipes or channels, being a motion outwards near the flow center and inwards near the walls. (ii) Secondary flow in straight pipes and channels of non-circular section, being a motion along

the walls toward corners or places of large curvature and from there to the center of the flow. This only occurs in turbulent flow. (iii) Secondary flow in pulsating flow. This is due to second order effects and is particularly striking with **ultrasonic waves**. (For other types of fluid flow, see entries following **flow**.)

FLUID FRICTION. The stresses which are set up in a fluid when it is distorted and which tend to convert the mechanical energy of the system to heat. Many simple liquids and most gases under ordinary conditions exhibit Newtonian viscosity, but suspensions and highly viscous liquids have more complicated responses to distortion.

FLUID, INCOMPRESSIBLE. A fluid whose density is substantially unaffected by change of pressure. The behavior of a real fluid is similar to that of an incompressible fluid only if the pressure variations in the flow are small compared with the bulk **modulus of elasticity**. For a fluid in motion in a gravitational field with velocities of order v , it is necessary that both v and \sqrt{gh} should be small compared with the velocity of sound in the fluid. (h is the depth of the fluid and g the acceleration due to gravity.)

FLUID MECHANICS. The study of the motion and forces acting upon fluids in motion and in equilibrium and including the forces exerted by such fluids on solids immersed in them. Hydrodynamics and aerodynamics are branches of fluid mechanics.

FLUID, NEWTONIAN. A fluid in which the viscous stresses are a multiple of the rate of distortion. The constant of proportionality is the fluid viscosity η . In symbols,

$$p_{ij} = \eta \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right)$$

where p_{ij} is the viscous stress in the direction of flow, transmitted across a surface parallel to

the flow. $\frac{1}{2} \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right)$ is the rate of strain tensor.

FLUID, VISCOUS. A fluid with an appreciable fluid friction, usually one in which the frictional stresses are described by a single Newtonian coefficient of viscosity, i.e., the

stress tensor p_{ij} is related to the rate of strain tensor

$$\frac{1}{2} \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right)$$

by

$$p_{ij} = \eta \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right)$$

where η is the fluid viscosity.

FLUORESCENCE. (1) The process of emission of **electromagnetic radiation** by a substance as a consequence of the absorption of energy from some other radiation, which may be either electromagnetic or particulate, provided that the emission continues only as long as the stimulus producing it is maintained. That is, fluorescence is a **luminescence** which ceases within about 10^{-8} sec after **excitation** stops; this period of time being the lifetime of an atomic state for a normal allowed transition. (2) The term fluorescence may also be applied to the radiation emitted, as well as to the emission process. (3) See **fluorescence, x-ray**.

FLUORESCENCE, X-RAY. In x-ray terminology, the term fluorescence may be used in the more specific sense (than given in the general definition above) to denote the characteristic x-rays (see **x-rays, characteristic**) emitted as a result of the absorption of x-rays of higher frequency.

FLUORESCENT SCREEN. A plate coated with a material readily fluorescent. It is used to observe certain patterns or other properties of invisible radiations, such as x-rays, from the fluorescent radiations emitted by the screen. It is also used to form the visible image in **cathode-ray tubes** as used in **oscilloscopes** and television tubes.

The distinction between fluorescent and phosphorescent screens is frequently not clearly defined. Fluorescent screens are properly those with only a very short glow-period after the exciting radiation (or electron beam) is extinguished.

FLUORINE. Gaseous element. Symbol F. Atomic Number 9. Atomic weight 19. Fluorine is a possible oxidizing agent for rocket fuels.

FLUTTER. In communication practice, (1) distortion due to variations in loss resulting

from the simultaneous transmission of a signal at another frequency, or (2) a similar effect due to phase distortion. (3) In recording and reproducing, the deviations in reproduced sounds from their original frequencies, which result in general from irregular motion during recording, duplication or reproduction. (4) An oscillation of definite period set up in any part of an aerodynamically active component by a momentary disturbance and maintained in a steady airstream by a combination of the aerodynamic, inertial and elastic characteristics of the member itself.

FLUTTER, PANEL. Dynamic instability of a panel subjected to airflow parallel to its equilibrium midplane.

FLUTTER SPEED. The speed for constant amplitude motion.

FLUX. (1) A quantity proportional to the surface integral of the normal (perpendicular) force field intensity over a given area.

$$\text{Flux} = K \int F_N dS$$

where F_N is the normal component of a field, (e.g., gravitational, electric, magnetic), and K is the constant of proportionality between the field and the flux density (**permittivity, permeability, etc.**). (2) A term which denotes the volume or mass of fluid or particles transferred across a given area perpendicular to the direction of flow in a given time.

There are many specific applications in physics of the term flux. For electromagnetic radiation, it signifies the energy per unit time, or the power passing through a surface. For photons or particles, flux is the number per unit time passing through a surface. In nuclear physics, flux commonly means the product nv , where n is the number of particles per unit volume and v is their mean velocity.

FLUXMETER. An instrument for measuring the strength of a magnetic field.

FLY-BACK. (1) The shorter of the two intervals of time which comprise a sawtooth wave. (See **wave, sawtooth**.) (2) The retrace motion of an electron-beam, as, for example, in a picture tube.

FLYING SAUCERS. The popular name given to unidentified flying objects seen by

persons all over the world. In most instances the objects seen have been natural objects such as balloons at high altitude, mock suns, the lights of distant objects reflected and refracted in the atmosphere because of unusual conditions of visibility, or aircraft mistaken in their configuration because of unusual lighting. "Saucer" sightings began to be made in large numbers in 1947, giving rise to extra-terrestrial explanations. On 7 January, 1948, at Fort Knox, Kentucky, Capt. T. F. Mantell, a National Guard pilot, chased a flying saucer to 20,000 feet and then, evidently "passing out", crashed to his death. Observers on the ground also saw the object and described it as an "ice-cream cone topped with red." Other trained observers have also seen and reported saucers. There have been over a hundred saucer sightings each year since 1947. In 1947 the Air Materiel Command of the U.S. Air Force was directed by the Headquarters, USAF to collect and evaluate all available facts concerning saucer sightings. The project led to no definite conclusions other than that the sightings were "unusual appearances of usual events." In 1952, approximately 1700 reports of saucer sightings were collected by the Air Force. In addition to visual sightings, both military and civilian radar installations have reported "sightings" involving performances beyond the capabilities of any known aircraft; e.g., hovering, rising vertically, turning abruptly at high speed and traveling at excessive speeds. Whether these events have been the result of temperature inversion, refraction due to water vapor at high altitude, actual vehicles from other planets, satellites of the earth not yet detected or any one of many other proffered explanations is not yet known.

In November, 1956, the "National Investigations Committee on Aerial Phenomena," an organization including, among others, Mr. Frank Edwards, the radio commentator, named a nine-man board of governors to provide "more honest information about flying saucers and space flight." Saucer crashes or landings in Mexico, Washington, D.C., and other locations have been reported. Reports have even included the finding of the bodies of "small men dressed in 15th century clothing" and other equally unlikely eye-witness observations. Sightings by supposedly experienced observers continue all over the world.

FLYING VEHICLE. A vehicle designed to fly through air or space.

FLYWHEEL EFFECT. The ability of a **resonant circuit**, because of its energy storage, to operate continuously from short pulses of energy of constant frequency and phase.

Fm. Fermium.

FM. Frequency modulation. (See **Modulation, frequency.**)

FM-CW RADAR. A radar set employing both the **frequency modulation** characteristics and the pulse of **CW** energy for target tracking information; the FM characteristic being used for velocity determination and the CW pulse being used for ranging.

FM/FM TELEMETERING. Telemetering. **FM/FM.**

FOCAL LENGTH. The property of a lens or curved mirror which determines the size of the image. In a simple lens the image of an infinitely distant object, such as a star, is formed at a distance from the lens equal to its focal length.

FOCUSING. The process of controlling the convergence and divergence of an electron beam, or of a beam of radiation.

FOEHN 73MM ROCKET. A German World War II air-to-air missile weighing approximately 57 pounds. It carried less than one pound of explosive. It was one of the first air-to-air missiles and was a solid propellant type converted from an Army ground rocket. It was designated as the RZ-73.

FOEHN WIND. On the lee side of mountains, air flowing downhill, dry-adiabatically, with attendant heating.

FOG. (1) Extra-spectral blackening of a photographic emulsion. (2) A two-phase system consisting of liquid or solid particles or droplets dispersed in a continuous gaseous phase. Condensation and consequent formation of water droplets (or ice crystals) in the air at the earth's surface will produce a fog. Fogs are classified in many ways. One of the simplest is the use of formation cause or process as a basis for differentiation among the various types, which has been followed in the following definitions.

FOG, ADVECTION. Fog that owes its existence to the flow of air from one type of surface to another. Surface temperature contrast between two adjacent regions is necessary in causing the formation of advection fogs. (1) The usual type of advection fog is formed when relatively warm and moist air drifts over much colder land or water surfaces. Examples of this type are found over land when moist air drifts over snow-covered areas, or over water when moist warm air drifts over currents of very cold water. The latter happens with southerly or easterly winds blowing from the Gulf Stream over the Labrador current. (2) Coastal and lake advection fog forms when warm and moist air flows offshore onto cold water (summer), or when warm moist air flows onshore over cold or snow-covered land (winter). (3) Sea smoke, arctic fog, or steam fog forms in very cold air when it flows over warm water.

FOG, RADIATION. A fog that develops in nocturnally-cooled air in contact with a cool surface. Radiation fog forms over land and not over water because water surfaces do not appreciably change their temperature during hours of darkness.

FOG, UPSLOPE. A fog caused by dynamic cooling in air flowing uphill. Upslope fog will form only in air that is convectively stable; never in air that is unstable, because instability permits the formation of cumulus clouds and vertical currents.

FOLDED DIPOLE ANTENNA. Antenna, folded dipole.

FOLLOW-UP SYSTEM. Colloquialism for servomechanism.

FOMALHAUT. Fomalhaut (Piscis Australis) is interesting as the most southern first-magnitude star visible from the latitude of New York. It rises almost simultaneously with Capella and is above the southern horizon during the evening in the autumn months.

FOOT-CANDLE. A unit of illuminance or luminous flux density when the foot is taken as the unit length. It is the illuminance on a surface one square foot in area on which there is a uniformly-distributed flux of one lumen, or the illuminance at a surface all points of which are at a distance of one foot from a

uniform source of one candle. The term is synonymous with lumen per square foot.

FOOT POUND. (1) A unit of work or energy in the f lbf s system of units, being the work done when an average force of one pound (force) produces a displacement of one foot in the direction of the force.

(2) A unit of moment or torque in the f lbf s system of units, being the time rate of change of angular momentum produced by a force of one pound acting at the end of, and perpendicular to, a radius of one foot from the axis of rotation. More commonly referred to as a pound foot (to distinguish from the unit of work).

FORCE. (1) In dynamics, the physical agent which causes a change of momentum, measured by the time rate of change of momentum. If the speeds involved are low compared with that of light, a force may be defined as proportional to the mass m of a body and to the acceleration a of the body which is produced by the force. Thus $f = kma$, where k is constant for a given system of units, and has the dimensionless value unity in length-mass-time systems or $1/g$ in length-force-time systems, g being the acceleration due to gravity. Force is a vector quantity, requiring both a magnitude and a direction for its complete specification.

(2) In statics, the physical agent which produces an elastic strain in a body. Static forces are equated to dynamic forces by the method of allowing a weight to produce a strain and then by allowing the same weight to fall under the action of gravity.

(3) From its initial conception, which was purely mechanical as expressed in (1) and (2), above, the term force extends to denote loosely any operating agency. (See **electromotive force**; **magnetomotive force** and other special entries under this term which follow.)

FORCE COEFFICIENT. Aerodynamic coefficients.

FORCE DIAGRAM. The graphical presentation of all the concurrent forces acting in a system, showing them in the proper vectorial dimensions and orientation, laid "tail-to-head." If the force system of the diagram forms a closed polygon, then the system is in equilibrium. If the diagram does not close, a line drawn from the tail of the first vector

to the head of the last corresponds in magnitude, direction and sense to the unbalanced force acting on the system. If the latter is a free body, its resulting acceleration is in the direction and sense of the unbalanced force, and is proportional to its magnitude.

FORCE, EFFECTIVE (EFFECTIVE MECHANOMOTIVE FORCE). In calculating loads on a structure imposed by complex forces the effective force is the root mean square of the instantaneous forces over a complete cycle. The unit is the **dyne**.

FORCE FIELD, CENTRAL. Central force field.

FORCE, IMPRESSED. Any external force acting on a particle in a dynamical system. The resultant force on each such particle can always be resolved into a resultant external impressed force and a resultant internal constraint force. Thus in the case of a particle suspended by a string, the weight is the impressed force and the tension in the string is the constraint force.

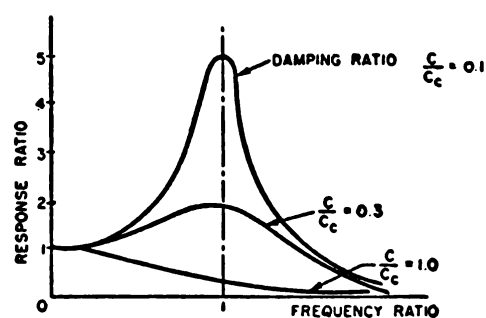
FORCE, INSTANTANEOUS (INSTANTANEOUS MECHANOMOTIVE FORCE). The instantaneous force at a point is the total instantaneous force.

FORCE, RESTORING. The elastic force which acts on a particle or portion of a mechanical system when displaced from equilibrium and whose direction is such as to return the system to equilibrium. In simple cases, the restoring force is linear, i.e., proportional to the first power of the distance. For some physical systems, however, the restoring force may be proportional to the second or higher power of the distance.

FORCED OSCILLATION. Oscillation, forced.

FORCED VIBRATION. Oscillation, forced.

FORCING FUNCTION. A description of the characteristics and identity of a source of excitation. The function may be linear, non-linear, harmonic or random. The response is a function of the input, the damping and the inertial characteristics of the forced member. (See figure.)



FREQUENCY RATIO = $\frac{\text{FORCING FREQUENCY}}{\text{NATURAL FREQUENCY}}$

RESPONSE RATIO = $\frac{\text{DYNAMIC RESPONSE}}{\text{STATIC RESPONSE}}$

DAMPING RATIO = $\frac{\text{ACTUAL DAMPING}}{\text{CRITICAL DAMPING}}$

Response to harmonic forcing function.

FOREIGN INTELLIGENCE. Information gathered by one nation in an effort to evaluate another nation's political and military capabilities and intentions.

FORMER. A light framework used as a shaping back-up for the skin covering of an aircraft or missile.

FORM FACTOR. (1) Factor introduced into a theory, usually by physical and non-rigorous arguments, to allow consequences of the theory to be computed without contributions from values of a parameter for which the theory is not applicable (see **cut-off**). (2) A means for describing one attribute of the shape of an **alternating-current** wave. The strength of a-c constantly varies in magnitude and direction. The effective value of a-c is equal to the d-c which will produce the same heating effect as the a-c wave, i.e., the root-mean-square (rms) value. The form factor is the ratio of the rms value of the wave to its average absolute value; the factor is unity for a square wave, and 1.11 for a pure sine wave. It is of importance in the measurement of waves containing harmonics, for it is the ratio of that reading on an rms meter to that of an ideal rectifier-type meter. (3) A term sometimes used for **coefficient of drag**.

FORWARD SCATTER. Extended range radio-wave propagation attained by forward scatter from the ionosphere.

FOUCAULT PENDULUM. In 1851 Foucault performed his celebrated **pendulum** ex-

periment at Paris, designed to give physical proof that the earth is in rotation about an axis. The pendulum, consisting of a very large iron ball suspended by a steel wire over 200' long, was suspended from the center of the dome of the Pantheon. Great care was exercised in the support for the wire so that no external forces should be effective at this point other than a vertical force to prevent the system from falling. On the floor, immediately under the pendulum, a layer of fine sand was placed so that the direction of the swing could be observed. The pendulum was started by drawing it to one side with a fine thread and, after the system was at rest, the thread was burned off, thus avoiding any initial lateral motion.

After such a pendulum is started swinging in one plane, it is soon observed that the plane of swing is apparently deviating slowly (in the clockwise direction in the northern hemisphere and the opposite in the southern). The rate at which the plane of swing deviates is equal to 15° per sidereal hour (cf **time**) multiplied by the sine of the latitude. Thus at the pole it would make a complete rotation in one sidereal day, while at the equator it would not rotate at all. At Paris (latitude $48^\circ 50'$ N.) the rate of deviations is about $11^\circ 18'$ per hour.

Foucault reasoned quite correctly that, in accordance with Newton's Laws of Dynamics, the direction in space of the plane of swing should not change unless the pendulum was acted upon by some external force other than that of gravitation and the counteracting force parallel to the direction of gravitation at the support. That the direction of the plane does apparently change can be accounted for only on the hypothesis that the earth is in rotation. Foucault's demonstration attracted wide scientific and popular attention and was accepted as a conclusive proof that the earth does rotate upon an axis, a fact which was not universally accepted at that time.

Fps. Feet per second.

Fr. Francium.

FRAGMENTING WARHEAD. Warhead, fragmenting.

FRAME. (1) In television and facsimile, the total area, occupied by the picture, which is scanned by the **picture signal**. (2) In motion

picture technique, one of a sequence of pictures taken rapidly.

FRAME FREQUENCY. (1) In television, the number of times per second that the **frame** is scanned. (2) In motion picture technique, the rate at which successive picture or frames are taken.

FRANCIUM. Radioactive element. Symbol Fr. Atomic Number 87.

FREE-BODY DIAGRAM. A diagram of a body, or part of a body, with the forces acting upon it indicated.

FREE ENERGY. There are two quantities to which this term has been applied. (1) The Gibbs free energy, which is also called the Gibbs function and the thermodynamic potential, is most generally understood when the term free energy is used without qualification. It is defined by the equation

$$G = U - TS + pV$$

where U is the internal energy (see **energy, internal**), T , the absolute temperature, S , the entropy, p , the pressure, V , the volume and G , the Gibbs free energy (the letter F is also widely used to denote this quantity). (See also **free energy change**.) (2) The Helmholtz free energy, which was called the psi function, and which is perhaps most commonly known as the work function. It is defined by the equation

$$A = U - TS$$

where U is the internal energy, T , the absolute temperature, S , the entropy and A , the Helmholtz free energy. (The letter ψ or the letter F are sometimes used instead of A for this quantity.) The decrease in A is equal to the maximum work done on the system in a constant-temperature, reversible change. In terms of the partition function, $A = -RT \ln Z$. Like the Gibbs free energy, the Helmholtz free energy is a thermodynamic potential, although the latter term is commonly used to refer specifically to the Gibbs free energy.

FREE ENERGY CHANGE. The change in the Gibbs free energy (see **free energy** (1)) for a chemical reaction, defined as

$$\Delta G = \sum_{r=1}^n \nu_r \Delta_f$$

where g_r is the molar Gibbs free energy of the r th component in the pure state, under the same conditions of temperature and pressure as those in which the reaction takes place. ν_r is the stoichiometric coefficient of the r th component.

This quantity ΔG is equal to the *maximum net* work available (i.e., work, other than work of expansion, in a reversible process) for a given change in state under constant temperature and pressure.

FREE FALL. The fall of a body toward the earth without guidance or retardation. During free fall the weight of all mass is zero and "weightlessness" would be experienced. Free fall is experienced by missiles traveling in unpowered trajectories through the stratosphere and higher, where the only force is that of the gravitational attraction of Earth, i.e., air resistance is not involved. The acceleration of free fall is $-g$.

FREE FLIGHT. (1) In general, motion without power, or motion after power has been shut off. (2) In particular, the flight of a guided missile or rocket after the fuel has been shut off or exhausted.

FREE-FLIGHT ANGLE. The acute angle between the horizontal and the longitudinal axis of a guided missile or space vehicle at the beginning of its free flight.

FREE-FLIGHT TRAJECTORY. That part of a ballistic missile's trajectory that begins with thrust cutoff and ends at re-entry. (See *re-entry trajectory*.)

FREE JET. A fluid jet without any solid boundaries, as a jet discharged into the open.

FREE MOLECULAR FLOW. (1) The flow of a gas in which the *mean free path* of a molecule is large compared to its size. The term is usually arbitrarily limited to flow rates in which the path is 10 times the molecular diameter, and is especially significant in the outer portions of the atmosphere, where it is many times that great. (2) Flow about a body in which the number of collisions between the molecules of the fluid is negligible compared to the collisions between these molecules and the body.

FREE ROCKET. A rocket unguided in its flight.

FREE RADICAL. An unsaturated molecular fragment in which some of the valence electrons remain free, i.e., do not partake in bonding. Examples are the methyl (CH_3) or phenyl (C_6H_5) radicals. Clear experimental evidence is available of their existence in various systems, especially in gaseous ones, although their half-life period at ordinary temperatures is of the order of thousandths of a second. The suggested use of free radicals as power sources for missiles and space ships is a natural consequence of the high values of the energy necessary to effect their dissociation, which becomes available when they recombine. One practical problem in their use arises from their instability, so that they are difficult to store. One proposal to solve this problem is to use very low temperature (**cryogenic**) techniques and/or magnetic suppression to stabilize them. Another possibility is to use the free radicals that always exist, though in very low concentration, in the upper **atmosphere**, where they are produced by intense radiation, and do not interact because of the relatively great distances between them. This plan would require a special type of engine to operate on such highly diffused fuel, possibly by carrying another fuel to burn with it. The energies available by recombination of certain atoms, such as those of hydrogen, are of the same order of magnitude as those of the free radicals. Furthermore, the problems to be solved in using atomic fuels are similar. For that reason, theoretical calculations are often made of the specific impulse values of various combinations of the two, as exemplified below:

PROPELLANT COMBINATION	SPECIFIC IMPULSE
2.8 H + 1 NH	410
2.2 H + 1 BH	420
5.0 H + 1 CH	490
0.5 H + 1 H	1040
H alone	1280

FREE RUNNING MULTIVIBRATOR. A relaxation oscillator using two connected tubes, with plate-to-grid feedback between them. The output is a square wave of a frequency between 1 cycle per minute and 100,000 cycles per second, with the exact frequency and amplitude determined by the particular circuit constants. The free running

multivibrator (FRMV), is used in radar applications to synchronize the **indicator sweep** with the transmitted pulse, i.e., the FRMV produces a reference indication on the scope at the same time that the ranging pulse is transmitted.

FREE STREAM. (1) The relative flow of air or other fluid undisturbed by the presence of a moving body. (2) The relative flow of air ahead of a **shock wave**.

FREEDOM, DEGREES OF. (1) The number of independent coordinates necessary for the unique determination of the position of every particle in a dynamical system is the number of degrees of freedom. Each degree of freedom is represented by a coordinate which can vary with time independently of all the rest. Thus a single particle which may move anywhere in three-dimensional space has three degrees of freedom. A particle constrained to move on a surface has two degrees of freedom. The six degrees of freedom of a missile are often taken as 3 coordinates of position and 3 of orientation (pitch, yaw and roll.)

(2) In the statement of the **phase rule**, one of that number of variable factors such as pressure, temperature or concentration, which must be fixed to define completely the state of the system.

(3) The number of independent **meshes**, or the number of independent **cut-sets** that may be selected in a **network**.

(4) In statistics, the concept of degrees of freedom refers essentially to the number of independent comparisons contributing to a root-mean-square estimate of **variance**. Thus, if the variance of a sample of N values is calculated from the sum of squares of deviations about the sample mean, the number of degrees of freedom (which is divided into the sum of squares to form the necessary mean square) is $N - 1$, since, if $N - 1$ of the deviations are given, the last one can be calculated from the necessary condition that the sum of the deviations must be zero. The degrees of freedom enter into distributions based on such estimates of variance.

FREON. Trade name for various chlorine and fluorine-containing carbon compounds used as working media in refrigeration cycles. Freons are also used in supersonic re-

search because in them sound travels only about 42% as fast as in air. Thus, a body traveling through Freon-12 at Mach 5 air velocity gives the same shock-wave patterns as a body traveling at more than twice that speed in air.

FREQUENCY. (1) In general, the number of repetitions of a periodic process per unit time, i.e., the inverse of the periodic time. (2) In electricity, frequency is the number of complete alternations per second of an **alternating current**. Sixty cycles per second is the standard frequency for a-c generation in the United States. Elsewhere 25 and 50 cycles per second have some vogue. In an alternator, the number of alternations per second of the output is the speed, in revolutions per second, multiplied by half of the number of poles. The number of poles in alternators is usually 2 or 4 for steam turbine-driven alternators, or 24, 26, 28, 30, 36, 48, or 60 in the case of engine-driven alternators. (3) In acoustics, the frequency represents the number of sound waves passing any point of the sound field per second. (4) In the case of light or other electromagnetic radiation, frequency may be expressed in this same way but is usually so enormous (500 million million per second for yellow light) that wavelengths or wave numbers (reciprocal of wavelength measured in cm) are ordinarily used instead. Radio frequencies are commonly given in thousands of cycles (kilocycles) or millions of cycles (megacycles) per second.

FREQUENCY ALLOCATION. The assigned carrier-frequency of a radio-transmitting station.

FREQUENCY ANALYZER. Analyzer, frequency.

FREQUENCY BAND. (1) The band or channel of frequencies associated with a **carrier** under **modulation**. (2) A group of different carrier frequencies all designated for the same purpose. Federal Communications Commission Notice 41510, published 5 October 1949 abolished the wartime code letter designations for radio frequency bands (random alphabetical series used as a security measure). The presently used International Frequency Band designations are:

FREQUENCY	DESIGNATION		WAVELENGTH	
10-30 kc/s	Very low	VLF	10^6 - 10^4 m	myriametric
30-300 kc/s	Low	LF	10^4 - 10^3 m	kilometric
300-3000 kc/s	Medium	MF	10^3 -100 m	hektometric (broadcast)
3-30 mc/s	High	HF	100-10 m	decametric (amateur)
30-300 mc/s	Very high	VHF	10-1 m	metric (line-of-sight)
300-3000 mc/s	Ultra high	UHF	100-10 cm	decimetric (old radars)
3000-38,000 mc/s	Super high	SHF	10-1 cm	centimetric (microwaves)
30,000-300,000 mc/s	Extremely high or Hyper high	EHF HHF	10-1 mm	millimetric

NOTE: HF region includes the short wave band; VHF and UHF comprise the ultra short wave band. Modern radars operate in the microwave region.

FREQUENCY, BASIC. That frequency of a periodic quantity which is considered to be the most important. In a driven system it is generally the driving frequency while in most periodic waves it would correspond to the fundamental frequency. (See **frequency, fundamental**.)

FREQUENCY, BEAT. When two signals of different frequencies are applied to a non-linear circuit, they will combine, or beat together, and give, among other components, one which has a frequency equal to the difference of the two applied frequencies. This difference frequency is known as the beat frequency.

FREQUENCY, CARRIER. Carrier frequency.

FREQUENCY, CENTER. (1) The average frequency of the emitted wave when modulated by a sinusoidal signal. (2) The frequency of the emitted wave without modulation.

FREQUENCY CONVERTER. A frequency changer in which the windings carrying the currents of different frequency are in the same magnetic field.

FREQUENCY DISCRIMINATOR. Discriminator.

FREQUENCY DISTORTION. Distortion which occurs as a result of failure to amplify or attenuate equally all frequencies present in a complex wave.

FREQUENCY, DOPPLER. Doppler shift.

FREQUENCY DOUBLER. A device delivering output voltage at a frequency that is twice the input frequency.

FREQUENCY DRIFT. The change in frequency of an oscillator as a function of time. The change may be due to changes in temperature, supply voltages, humidity, or physical dimensions caused by wear.

FREQUENCY, FREE-RUNNING. The frequency at which an oscillator operates in the absence of a synchronizing signal.

FREQUENCY, FUNDAMENTAL. (1) The lowest possible frequency of vibration of a system characterized by normal modes of vibration (for example, a vibrating string or organ pipe). (2) The greatest common divisor of the component frequencies of a periodic wave or quantity. (3) The frequency of a sinusoidal quantity which has the same frequency as a periodic quantity.

FREQUENCY, FUNDAMENTAL NATURAL. The lowest of a set of natural frequencies. (See **frequency, natural**.)

FREQUENCY HARMONICS. The permissible characteristic frequencies of a vibrating system subject to boundary restrictions (for example, a stretched string fastened rigidly at both ends, an organ pipe open at both ends, etc.). The lowest permissible frequency is called the fundamental. The higher frequencies are called the 2nd, 3rd, 4th, etc., harmonics. The fundamental is ordinarily referred to as the first harmonic. (See **overtone**.)

FREQUENCY, INFRARED. In the electromagnetic spectrum the range of invisible radiation frequencies which adjoins the visible red spectrum and extends to microwave radio frequencies.

FREQUENCY, INTERMEDIATE (IF). In superheterodyne radio reception, the interme-

diate frequency is that frequency resulting from the combination of the received frequency with a locally generated frequency, and is usually equal to their difference. Its use facilitates amplification and detection.

FREQUENCY METER. Most modern frequency meters for radio use are not instruments in the usual sense but are really several instruments and associated apparatus. The old absorption type wavemeter might be called a single instrument, but it is not used except for rough measurements. It consists of a coil and capacitor in series with some sort of indicator. Modern precision measurement of frequency utilizes a comparison process. The fundamental for this is the rotation of the earth. High-grade crystal oscillators are used to generate medium values of radio frequency, the output being compared with the rotation of the earth by synchronous clocks or by comparison with another oscillator which is so checked. Associated with this oscillator are various multi-vibrator oscillators serving as frequency dividers to give an extensive series of accurately known frequencies. The frequency to be measured is compared with the closest of these known frequencies by heterodyning and the resultant difference frequency (an audio frequency) determined in one of several ways. Very high frequencies are measured by exciting standing waves on an open or shorted transmission line and measuring the linear distance between nodes or anti-nodes of these waves. The frequency is then obtained by dividing the velocity (3×10^{10} cm/sec) by the wavelengths in centimeters. For very accurate measurements several corrections must be applied to this method but it is sufficiently accurate for many purposes without the corrections.

FREQUENCY MODULATION (FM). Angle modulation (see **modulation, angle**) of a sine-wave carrier in which the instantaneous frequency of the modulated wave differs from the carrier frequency by an amount proportional to the instantaneous value of the modulating wave. Combinations of phase and frequency modulation are commonly referred to as "frequency modulation."

FREQUENCY MONITOR. A device which gives a continuous indication of any departure

of a radio transmission frequency from its assigned value.

FREQUENCY MULTIPLIER. A non-linear network or other device for generating harmonics of a sinusoidal input, and having means for selecting a certain harmonic as its output.

FREQUENCY, NATURAL. (1) That frequency at which a body or system will vibrate if displaced and allowed to oscillate freely. A tuning fork vibrates at its natural frequency. Most vibrating systems have many natural frequencies, usually harmonics of the fundamental. (2) The frequency at which the inductance of a coil and its distributed capacity produce resonance. (3) The lowest frequency at which there is a standing wave on an antenna.

FREQUENCY, PULLING. The tendency of a modulation stage to change the frequency of a direct-coupled master oscillator.

FREQUENCY, RADIO. The frequencies of electromagnetic radiation used for the transmission of radio signals through space, generally ranging from 90,000 cycles per second, in long wave transmission, to 400,000,000 or more cycles per second in short wave transmission.

FREQUENCY, RESONANT. Resonance.

FREQUENCY RESPONSE. The range of frequencies passed with an allowable loss by a circuit or device, such as an audio amplifier, a microphone or a loudspeaker.

FREQUENCY RESPONSE ANALYSIS. A method of evaluating a control system by introducing a varying rhythmic change (e.g., alternating current) into a process or control unit to determine what effect, if any, these changes will have. It is possible to use this method of analysis to predict what the addition of new equipment will mean to the operation of a control system.

FREQUENCY RESPONSE FUNCTION. A term which is descriptive of the performance of a component in a dynamic system, i.e., the Fourier transform of the impulse response. It is also the ratio of the Fourier transform of the network output to the Fourier transform of the network input.

FREQUENCY RESPONSE METHOD. A technique for analyzing **servo mechanism** performance. It utilizes the fact that a linear system, when subjected to a sinusoidal disturbance, will demonstrate a steady state sinusoidal response of the same frequency but differing in phase and amplitude from the input. The characteristics of the servo are then defined in terms of resulting change in amplitude and the phase shift over the frequency regime of interest. This method gives stability information directly from the open-loop transfer function.

FREQUENCY, SERVO-CORNER. Servo-corner frequency.

FREQUENCY SHIFT KEYING. A form of frequency modulation in which the modulating signal shifts the output frequency between predetermined values and the output wave is coherent, i.e., with no phase discontinuity. It is abbreviated *FSK*.

FREQUENCY, SIDE. One of the frequencies of a **sideband**.

FREQUENCY STABILIZATION. The process of controlling the center frequency (see **frequency, center**) so that it differs from that of a reference source by not more than a prescribed amount.

FREQUENCY STANDARD. The standard of frequency used in frequency measurement (see **frequency meter**), usually an extremely stable, crystal-controlled **oscillator**. The fundamental standard is the rotation of the earth, and other standards are checked against this. Standards which may be checked directly (by means of synchronous clocks) are called "primary standards," while those which are checked against primary standards are called "secondary standards."

FREQUENCY, SUBCARRIER. In telemetering, an intermediate frequency that is modulated by intelligence signals and, in turn, is used to modulate the radio carrier either alone or in conjunction with subcarriers.

FREQUENCY TRIPLER. A device delivering output voltage at a frequency that is three times the input frequency.

FREQUENCY, WEATHERCOCK. The frequency of the characteristic motion of a

missile airframe as it returns to its steady state condition after a disturbance has produced an unbalanced moment.

FRESCANAR. A frequency scanning radar technique developed by Hughes Aircraft Company. The AN/SPS-26 shipboard radar system uses this principle.

FRETTING. Physical damage caused by chafing, rubbing, or wearing away.

FRETTING CORROSION. Fretting accelerated by corrosive action.

FRICTION. The resistance to relative movement of two surfaces in contact with one another.

FRICTION, COEFFICIENT OF KINETIC (SLIDING). For two surfaces, the ratio of the tangential force which is required to sustain motion without acceleration of one surface with respect to the other, to the normal force which presses the two surfaces together. It is generally less than coefficient of static friction.

FRICTION, COEFFICIENT OF, STATIC. For two surfaces, the ratio of the maximum tangential force which is required initially to produce motion of one surface with respect to the other, to the normal force which presses the two surfaces together. It is generally greater than coefficient of kinetic friction.

FRICTION LAYER. (1) The lower layer of the **troposphere**, in which the friction of the air against the earth's surface affects the movement of the air. (2) The boundary layer in an airflow.

FRICTION, MECHANICAL. The chief causes of friction are the interlocking of the minute irregularities on the rubbing surfaces, adhesion between the surfaces, and the indentation of the softer by the harder body. Friction between solid bodies may be classified as sliding and rolling. The laws of sliding friction were investigated by Coulomb, who found that, approximately and within limits, (1) the friction between two surfaces is slightly greater just before motion begins than when the surfaces are in steady relative motion; (2) the friction is proportional to the force pressing the surfaces together; (3) it is independent of the area of contact, and (ex-

cept at start) of the speed of relative motion. The constant ratio of the friction to the force pressing the surfaces together is called the coefficient of friction, some typical values of which are as follows:

Dry wood on dry wood	0.35
Leather on metal	0.55
Iron on stone	0.50
Wood on stone	0.40
Stone on stone or brick	0.65
Well-oiled metals	0.05

By means of such coefficients, it is possible to calculate what the friction will be between two bodies, as a wooden sill on a stone foundation, when the force pressing them together is given.

The tangent of the angle at which a plane surface must be inclined for a solid block to slide steadily down it is the coefficient of sliding friction between plane and block. Lubrication greatly reduces the coefficient by separating the solid surfaces. Rolling friction, due to the indentation of the surfaces in rolling contact, is much less than sliding friction, as illustrated by the use of ball-bearings. The viscosity of liquids and gases is sometimes called "internal friction," as is the dissipation of energy in a vibrating solid.

FRICTION, ROCKET MOTOR. The acceleration of the gas particles in the motor yields a stable flow with thin boundary layers on the walls. In these layers a strong shear force is generated due to the extremely steep velocity gradient between wall and main stream. In comparison, the internal friction of the gas is negligibly small if the velocity distribution is fairly homogeneous. In a rocket motor this is not always the case. It depends on the injection system and correct chamber pressure. Therefore the losses due to internal friction in a rocket motor are larger than, for instance, in an air nozzle.

These losses can be subdivided into two portions, one resulting from friction in the combustion chamber, the other from friction in the nozzle. If different nozzles of the same expansion ratio but with different half angles are attached to the same chamber, the first portion remains constant while the nozzle friction increases proportionally to the increase in surface area. As the expansion ratio proper is increased, nozzle friction

changes due to increased nozzle length, and to a higher average flow velocity.

FRICTIONAL FORCES. Types of forces used to overcome friction in a mechanical system: (1) *Static*: A discontinuous force independent of the output until the static friction is broken. (2) *Coulomb*: A constant force substantially independent of velocity and opposite to the motion. (3) *Viscous*: A force proportional to velocity of the output member.

FRICTIONAL HEATING CONTROL. The passage of air over solid surfaces produces heat, particularly at supersonic speeds where considerable compression occurs. Therefore, methods of cooling, or other means for overcoming the heating effects are important, especially for airplane passenger cabins or space ships. Surfaces exposed to such heating are constructed of heat-resistant materials, the development of which is a major research activity. Refrigeration of exposed surfaces, and even of cabin walls, is a possible method, subject to the disadvantageous addition of weight which it entails. Experiments have been made of applying liquid helium to wing edges and other exposed surfaces to reduce heat transfer; they have yielded good results, in spite of their technical difficulties.

Various proposals for cooling missiles include the use of a false outer skin which can be allowed to ablate. Other methods are the use of ceramics having high temperature resistivity, or of double-walled skins with circulating cooling liquids or of porous outer walls using transpiration cooling. Some of the methods cited are obviously of short duration. This consideration is not necessarily a drawback, because the frictional heating continues only during travel through the atmosphere. Since its effect becomes serious only above about Mach 2 for manned space vehicles, and Mach 5 for unmanned ones, methods of slowing the re-entry are under consideration, such as decelerating by use of retro-rockets. At Mach 2, frictional heating gives temperatures as high as 400°F. Aluminum alloys lose half their strength at 450°F. Mach 12 can produce a temperature of approximately 5000°F, which exceeds the melting temperature of many ceramics. A recent theory concerning frictional heating states that the configuration giving the most rapid deceleration should give

the least frictional heating, therefore a high **drag-to-weight** ratio is good re-entry design.

FRITZ X. A German World War II steerable bomb also identified as FX-1400, the number referring to the weight in kilograms. It was 10 feet long, 20 inches in diameter, with four "X"-shaped wings. The tail consisted of a flattened-out octagonal structure encircling cruciform stabilizing fins. First models were radio controlled and a later type used drag wires. The radio controlled version used the Strassburg-Kehl radio command link system. The first Fritz-X was flown in February 1942; it was used in 1943 against Allied shipping and assault vessels off Salerno, Italy, released from approximately 20,000 feet altitude some 4-5 miles from ship targets. This missile sunk the Italian battleship ROMA. It was also called the X-1 or SD-1400-X.

FRONT. (1) A line on the earth's surface at the intersection of a frontal surface with the earth; a line on a map representing this intersection. (2) In an occlusion, a line on top of a cold air mass at the intersection of the warm air mass with the less cold air mass. Usually called "upper front." (3) A **frontal surface**. (4) The weather connected with a frontal surface. (5) The airspace in which such weather prevails.

FRONT, COLD. A front along which colder air replaces warmer.

FRONT, INTERTROPICAL. In meteorology, the boundary between the trade wind system of the northern and southern hemispheres. It manifests itself as a fairly broad zone of transition commonly known as the doldrums.

FRONT, OCCLUDED. A front along which a cold front overtakes a warm front.

FRONT, PRESSURE. Shock front.

FRONT, QUASI-STATIONARY. In meteorology, the ideal stationary front is seldom found in nature, but it often occurs that the frontal movement is such that no appreciable displacement takes place. The front is then said to be quasi-stationary.

FRONT, SECONDARY. A second front of similar nature to and following fairly closely behind a primary front. A disturbance con-

nected therewith is called a secondary disturbance.

FRONT, STATIONARY. A front along which one air mass does not replace the other, thus tending toward unchangeable weather.

FRONT-TO-BACK RATIO. The ratio of the effectiveness of a directional antenna, microphone or loudspeaker as measured toward the front and toward the rear.

FRONT-TO-REAR RATIO. Front-to-back ratio.

FRONT, WARM. A front along which warmer air replaces colder.

FRONTAL SURFACE. A slanting or sloping surface or layer of discontinuity existing between two air masses having different characteristics.

FRONTOGENESIS. The origination or creation of a front by the motion and meeting of different air masses, or the process by which this takes place.

FRONTOLYSIS. The dissolution or breaking up of a frontal surface.

FROUDE'S NUMBER. In fluid mechanics, a dimensionless parameter defined as follows:

$$F = \frac{V^2}{Lg}$$

where F is the Froude number, V is the velocity of flow, L is the length of the flow and g is the gravitational acceleration.

FROZEN EQUILIBRIUM. One of the theoretical assumptions upon which rocket gas dynamics is based. It assumes, for purposes of computation, that the expanding gases exhausted through a motor **nozzle** remain at the same composition as when leaving the **combustion chamber**. That is, that the ratio of specific heats, molecular weight, combustion temperature, gas constant, and other parameters remain the same throughout the flow.

FRUIT. Hash.

FSA. Federal Security Agency.

F SCOPE. A radar scope which presents the azimuth error angle of a target by a horizontal displacement of the target spot on the face

of the scope, and the elevation of the target by a vertical displacement.

FSE. Field support equipment.

FSN. Federal stock number.

F STOFF. (1) A German World War II code name (Air Ministry) for hydrazine hydrate fuel. It was also called Bertolin. (2) In World War I, the German code name for titanium tetrachloride.

FTCC. Flight Test Coordinating Committee.

FUEL. A substance which yields thermal or nuclear energy by undergoing any one of a number of reactions. Thus, **nuclear fuels** undergo nuclear reactions, which derive their energy from changes in the mass of nuclei of atoms; while **chemical fuels** undergo reactions of rearrangement of atoms to form different molecules. In the latter case, the term "fuel" is restricted to the reactant which undergoes oxidation. (See also **propellant**.)

FUEL CONSUMPTION. The amount of fuel used per horsepower-hour. In popular terms the fuel consumption may also be expressed as a rate of burning of fuel per unit distance traveled or per unit time. (See also **specific fuel consumption**.)

FUEL DISPERSAL SYSTEM. In missile proving ground practice, an inflight safety device providing for the dissipation of missile propellants by means of some forceful rupturing of the fuel containers. Such a system is intended to render the missile less of a hazard in the event that flight termination must be commanded because the missile is erratic. The theory is that dissipating the fuel presents a less concentrated explosive hazard when the missile impacts. However, the advantages of the attempt to reduce the ground hazard are debatable since fuel dispersal action may actually do more ground damage by also dispersing missile fragments over a wider area, because such a system usually includes explosives which unavoidably detonate the propellants, in keeping with the objective, "to disperse and burn the propellants before they reach the ground." Unquestionably there is some minimum altitude below which it is senseless to execute fuel dispersal, since launching areas are intentionally constructed to protect firing crews from such hazards as

exploding missiles. The problem is then to determine when the fuel dispersal system should be applied. An erratic missile flying over facilities which are desired to be protected from direct impact presents an almost insoluble problem of when to blow the charge. Also, the inclusion of a fuel dispersal system involves the use of explosives and the presence of these in the missile prior to launching endangers the launching crew and, in the event of misadventure, may subject a few persons to certain death (those working next to the missile) in order to protect many others.

FUEL RESERVE. Specifically, an amount of fuel carried in excess of that calculated to be sufficient for a given flight.

FUELS, EXOTIC. A popular term for high energy fuels. (See **fuels, high energy**.)

FUELS, HIGH ENERGY. Fuels with higher heat content than the hydrocarbon fuels (usually in the range of 25,000 Btu/lb). Boron compounds are frequently the basic ingredient.

FUELS, ZIP. (1) A popular term for high energy fuels. (2) A U.S. Air Force project (formerly BuAer) with the objective of developing high performance, non-hydrocarbon fuels, e.g., boron-compound based fuels.

FUGACITY. A quantity which measures the true escaping tendency of a gas, a sort of idealized pressure. If primes and double primes refer, respectively, to an ideal gas and a real gas, the $dF' = V'dp = RT \, d\ln p$, and $df'' = V''dp = RT \, d\ln f$, where dF is a change in free energy or chemical potential, produced by a change in pressure, dp ; V is the volume of the gas at the absolute temperature T , f is its fugacity and R is the gas constant.

FULL WAVE. In electricity, one complete cycle of an alternating current which thus contains positive and negative maxima, as contrasted to a half-wave, which is either the positive or negative part of the cycle. A full-wave rectifier, for example, operates on both halves of an a-c cycle.

FULL-WAVE RECTIFIER. Rectifier, full-wave.

FUNCTION. (1) A mathematical expression describing the relation between variables; the

function taking on a definite value, or values, when special values are assigned to certain other quantities, called the arguments, or independent variables of the function. If there is one independent variable, the dependent variable y may be determined by the equation $y = f(x)$; if there are several independent variables, by $y = f(x_1, x_2, \dots, x_n)$. (2) A term referring to an activity of an armed service in the furtherance of war, e.g., mine-laying is a function of the U.S. Navy.

FUNCTION GENERATOR. A device having an output which is: (1) a single specified mathematical function of the input; (2) one of several such functions at the control of the operator of the device; (3) an arbitrary modification of the input as imposed by a calibration curve or other arbitrary function.

One type of function generator is used in the linearization of **telemetry** data. In it an electronic-optical **servo** loop, consisting of a **cathode ray tube**, calibration mask, **photo-multiplier tube** and **feedback** d-c amplifier are used. The calibration mask is placed in front of the cathode ray tube on a lantern slide, and shows an opaque lower area and a transparent upper area, the dividing curve being the linearizing function. The slide carries a calibration curve, which is a combination of the end instrument calibration curve and the telemetry link calibration curve. The electronic-optical servo loop causes the cathode ray tube to ride the edge of the curve on the lantern slide mask. This creates an output voltage proportional to the ordinate of the calibration curve, which is applied to the telemetry data as an arbitrary correction. Thus, this type of function generator is called an "arbitrary function generator." A systematic function generator has an output that is a specified mathematical function of the input.

FUNCTION, PERIODIC. A function for which a constant a exists so $f(z) = f(z + na)$, where n is an integer. The function repeats itself periodically with the fundamental period a . Typical examples are $\sin z$, $\cos z$, with fundamental period 2π ; e^z , with fundamental period $2\pi i$. Functions may be doubly periodic such that the periods are of the form $(na + n'a')$, both n and n' integers but not both zero.

FUNCTION, STEP. (1) A piece-wise constant function. For example, $f(x) = 0$ for

$x < 0$ and $f(x) = 1$ for $x > 0$. (2) A pulse signal, as fed to a servo system.

FUNCTIONAL RELIABILITY. Reliability, functional.

FUNDAMENTAL FREQUENCY. Frequency, fundamental.

FURALINE III. A furfuryl alcohol-based fuel used in the French SEPR 481 rocket engine.

FURAN. A liquid propellant rocket fuel consisting of a mixture of furfuryl alcohol and aniline. It is normally burned with red fuming nitric acid as an oxidizer.

FURFURYL ALCOHOL. An organic compound having the chemical composition of $C_4H_3O \cdot CH_2OH$. It is a yellowish liquid having a melting point of $-24^\circ F$, boiling point of $340-385^\circ F$, a density of 1.13 gm/cc at $68^\circ F$, specific gravity of 1.138, and molecular weight of 98.1 lb/mole.

FUSE. A slow burning device used to transmit a flame. (See also **Fuze**.)

FUSE, BICKFORD. Bickford fuse.

FUSE, MINER'S. Bickford fuse.

FUSE, SAFETY. Bickford fuse.

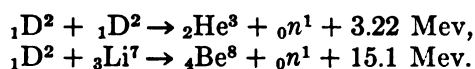
FUSEE. A strong burning pyrotechnic device used as a rocket igniter.

FUSELAGE. The body of an air vehicle.

FUSION. A change from the solid to the liquid phase of matter. In crystalline bodies, and, we are beginning to understand, also in many other solids not exhibiting well-defined **crystal structure**, the atoms are held in positions of stable equilibrium by intermolecular forces. They move of course with thermal agitation, but their movements are oscillatory and do not carry them outside a limited range of distance from their equilibrium positions. If a solid body is sufficiently heated, the molecules break loose from their stable configuration and wander about or diffuse among each other. When this condition has become general, the body exhibits the characteristics of a liquid, and we say it has undergone fusion. In some cases, such as ice, the change is quite

abrupt, the substance having a well-defined melting point; in others, like glass or pitch, it is gradual. The difference is probably due to the more uniform potential energy of the atoms in the former case, so that they all "break loose" at the same stage of thermal agitation; while in the latter case some atoms require more energy to dislodge them than others. In any case the process requires a supply of energy which is recognized as the heat of fusion. With most substances, fusion is accompanied by an increase in volume; but with some, like ice, the volume becomes definitely less.

FUSION, NUCLEAR. The combination of two light nuclei to form a heavier nucleus, with the release of the difference of the nuclear **binding energy** of the products and the sum of the binding energies of the two light nuclei. Examples are:



Fusion reactions can take place only if the reacting nuclei possess sufficiently high energies to overcome their mutual Coulomb repulsion and to approach within the range of nuclear forces, hence they are favored by high temperatures. (See also **thermonuclear reaction, carbon cycle, proton-proton chain.**)

FUZE. That component of the armament which recognizes the optimum time for destruction of a target by a missile and initiates explosive elements leading to the detonation of the warhead at that time.

FUZE, AGENTS. Natural phenomena utilized for the purpose of recognizing target characteristics useful for fuzing.

FUZE, AMBIENT. Ambient Fuze.

FUZE, CONTACT. Fuze, Impact.

FUZE, IMPACT. A fuze, as for a bomb, in which the action is initiated by the force of impact. Sometimes termed a contact fuze.

FUZE, INFLUENCE. A proximity fuze.

FUZE, PROXIMITY. A fuze which initiates the warhead as a consequence of a determination that a target is within some specified region near the fuze, but not by contact with the target.

FX 1400. German guided bomb, used in World War II.

FZG-76. The official German World War II designation for the V-1 flying bomb. The letters stood for Flugzeuge 76 (i.e., Aircraft 76). The missile's code name was Kraehe. (See also V-1.)

G

G. (1) Gram (g). (2) Gravitation acceleration (g), local gravitational acceleration (g_L), standard gravitational acceleration (g_0). (3) Acceleration of free fall (g). (4) Newtonian gravitational constant (G). (5) Electrical conductance (g or G). (6) Grid or input conductance (g_p), thus g designates the grid of a tube, either as a subscript or as a symbol on a circuit diagram. (7) Plate conductance (g_p) tube transconductance (g_m). (8) Degeneracy (statistical weight) (g). (9) Modulus of shear elasticity (G). (10) Gibbs function (or free energy) (G , though F is also in common use). (11) Glauert number (G). (12) Grashof number (G). Mass flow per unit area per unit time (G). (See also entry following.)

g. A symbol or abbreviation for acceleration of gravity. At the surface of the earth, its value is 32.2 feet per second per second (or 8×10^4 miles per hour per hour). Other accelerations (such as that encountered by a pilot executing high speed maneuvers wherein he experiences centrifugal accelerations, or the linear acceleration of a missile on take-off) are expressed as multiples of this value. The human body can easily withstand accelerations of 5 g with little adverse effect, and can withstand accelerations for short periods by taking advantage of reclining postures, tight-fitting body-restraining pressure suits and other counteracting devices. The effect of exceeding the g-tolerance for man is unconsciousness. Monkeys and other animals have successfully resisted decelerating forces of up to 25 g without permanent ill effects. In laboratory tests, men in human centrifuges have been subjected to 15 g stresses for 5 seconds, the principal effect being production of small blood blisters on the skin. Lt. Col. John P. Staff, USAF surgeon, traveled 995 miles an hour and then came to a stop in 1.4 seconds. This subjected him to 40 g of deceleration. He suffered neither loss of consciousness nor permanent injury. (See **gravity**.)

G FACTOR (LIMIT). The ratio of the maximum acceleration that an object can withstand to the acceleration of gravity. It is equivalent to the ratio of the maximum accelerating force that the object can withstand to the weight of the object. The G factor for an object depends in part on the time duration of the accelerating force. Caution should always be exercised to ascertain, insofar as practicable, how this value was determined.

Ga. Gallium.

GADOLINIUM. Rare earth metal. Symbol Gd. Atomic Number 64.

GAIN (TRANSMISSION GAIN). (1) A general term used to denote an increase in signal power in transmission from one point to another. Gain is usually expressed in decibels and is widely used to denote transducer gain. (See also **amplifier**; **antenna, directional**.) (2) The ratio of the output of a **transducer** to the input, even when these quantities are not measured in terms of power. Thus we refer to the voltage gain or current gain of an amplifier.

GAIN, DIRECTIVE. Directive gain.

GAIN FUNCTION. The ratio of the power radiated by an antenna in a given direction per unit solid angle to the average power radiated per unit solid angle. It is independent of the actual power level but expresses the increase in power radiated in a given direction by that particular antenna over what would be radiated from an isotropic radiator emitting the same total power. The maximum value of the gain function is called "gain." The gain function is expressed mathematically as follows:

$$G(\theta, \phi) = \frac{P(\theta, \phi)}{P_i/4}$$

Where, $G(\theta, \phi)$ is the *gain function*, θ is the colatitude angle, ϕ is the azimuth angle.

$P(\theta, \phi)$ is the power radiated per unit solid angle in the direction θ , ϕ , and P_t is the total power radiated.

GAIN, INSERTION. Insertion gain.

GAIN MARGIN. In feedback systems, a stability criterion which indicates the increase in gain which would be required to cause oscillation. It is expressed as the reciprocal of the magnitude of the loop gain at the frequency where the phase shift is -180° . Otherwise stated, it is the number of decibels, expressed in decibels below unity gain at a selected frequency, for which the phase magnitude equals 180° .

GAIN OF ANTENNA. Antenna, gain of.

GAL. An acceleration of one centimeter per second per second. The gal is the unit of acceleration used by the U.S. Coast and Geodetic Survey in stating values of gravity. The term is not an abbreviation but a unit named to honor Galileo. The practical unit used is the milligal.

GALACTIC COORDINATES. As the modern theories regarding the structure of the sidereal universe became more and more firmly established, it became necessary to have a system of spherical coordinates for the representation of points relative to the plane of the Milky Way, or the galactic plane.

The galactic coordinate system is a system of spherical coordinates having as its fundamental plane the plane of the Milky Way (or galaxy). The adopted position of the pole of this plane is $12^h 40^m$ right ascension and 28° north declination. The plane of the Milky Way cuts the plane of the celestial equator at an angle of 62° . Galactic latitude is measured perpendicular to the plane of the galaxy along great circles drawn through the galactic poles and hence perpendicular to the galactic plane. Galactic longitude is measured in the plane of the galaxy from the point where this plane cuts the plane of the equator in right ascension $18^h 40^m$ to the point where the great circle perpendicular to the galactic plane through the object intersects the galactic plane.

GALACTIC SPACE. Space, galactic.

GALAXY. (1) The group of several billion stars, star clusters, nebulae, etc. to which the

sun belongs, and which is also called the "Milky Way." (2) Any of the very numerous groups of stars similar to the Milky Way, which form isolated units in the universe.

GALCIT. Guggenheim Aeronautical Laboratory, California Institute of Technology; Pasadena, California.

GALCIT PROPELLANTS. A family of solid propellants developed by the Guggenheim Aeronautical Laboratory of the California Institute of Technology. They contained approximately 75% by weight of potassium perchlorate and 25% by weight of an asphalt-oil mixture (70% Texaco Number 18 asphalt and 30% Union Oil Company Pure Penn SAE 10 lubricating oil), which served as both the fuel and a binder. Specific impulse typical of these was 185 lb-sec/lb, somewhat lower than double-base powders. Their advantage was that they were about $\frac{1}{2}$ as sensitive as ballistite to temperature changes. However Galcit propellants became brittle at low temperatures and soft at high, and so caused cracking or deformation of burning surfaces respectively. When the burning surface became larger than normal, it sometimes caused motors to explode from the greater pressures.

GALE. A wind of 40-48 miles per hour velocity. (See Beaufort scale.)

GALLIUM. Metallic element. Symbol Ga. Atomic number 31.

GALVANOMETER. An instrument for measuring electric currents, usually by means of their magnetic effect. Observations are made by noting the deflection produced by the torque exerted between an electric circuit and a magnet. Galvanometers may be divided broadly into two classes, according to whether the coil is stationary and the magnet turns, or vice versa.

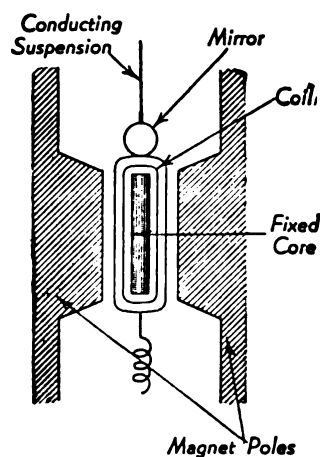
Perhaps the most highly developed of the first type is the Kelvin astatic galvanometer (see galvanometer, astatic). Among galvanometers of the second type, the best known is the d'Arsonval galvanometer (see galvanometer, d'Arsonval). There are also string galvanometers, in which a straight, slender wire carrying the current is thrust to one side by the magnetic field; and vibration galvanometers in which the string vibrates in syn-

chronism with the alternating current traversing it.

GALVANOMETER, ASTATIC. A galvanometer which gives readings independent of the earth's magnetic field by means of a construction feature in which readings of current are obtained by passing the current through a coil around a system of two movable needles with opposing magnetic fields.

GALVANOMETER, BALLISTIC. A galvanometer which is used most commonly to measure the total quantity of electricity in a transient current, and is accordingly designed to have a long period of swing (high moment of inertia) of its moving element.

GALVANOMETER, D'ARSONVAL. A moving-coil galvanometer in which the magnet is a fixed, permanent magnet of the horseshoe or double-horseshoe form, with a light, rectangular coil suspended in the strong field between its poles, the suspension carrying the feeble current. The current causes the coil to turn in the field. Often a fixed iron core is supported inside the moveable coil to concentrate the field.



Essential parts of D'Arsonval galvanometer.

If these galvanometers are undamped, they will give a "throw" when a charge of electricity is sent through them, and the charge can be thereby measured. Such an instrument, with a heavy coil, called a ballistic galvanometer, is useful in capacitance measurements. The oscillations may be damped by shunting.

GALVANOMETER, MOVING-COIL. A galvanometer in which a current-carrying coil is deflected by a fixed magnetic field.

GALVANOMETER RECORDER. A combination of mirror and coil suspended in a magnetic field. The application of a signal voltage to the coil causes a reflected light beam from the mirror to pass across a slit in front of a moving photographic film, thus providing a photographic record of the signal. Other galvanometer recorders use a photoelectric system so arranged that the motion of the mirror drives a "slave coil" which carries a pen and records the magnitude of the signal on a moving paper chart.

GAM. Guided Aircraft Missile.

GAM-63. Rascal.

GAM-72. Quail.

GAM-77. Hound dog.

GAMMA RAY. A quantum of electromagnetic radiation emitted by a nucleus as a result of a quantum transition between two energy levels of the nucleus. Gamma ray energies range from 10^4 to 10^7 ev, with correspondingly short wavelengths and high frequencies, and their ability to penetrate matter is high. They follow transitions that leave the product nuclei in excited states, as well as in many induced nuclear reactions.

GANGED DEVICE. Two or more components connected so that adjusting of one makes the same adjustment to all. Switches and variable condensers are the most common ganged devices.

GANTRY. A frame structure raised on side supports to span a missile, usually traveling on rails which may be used for erecting and servicing large bombardment-type missiles. It can be positioned directly over the launching site and rolled away just prior to firing.

GANTRY CRANE. A large crane mounted on a platform that runs back and forth on parallel tracks.

GANTRY SCAFFOLD. A massive scaffolding structure mounted on a bridge or platform supported by a pair of towers or trestles that run back and forth on parallel tracks, used

to service a large **rocket** as it rests on its launching pad.

GAPA. Ground to Air Pilotless Aircraft. It was the name of a missile project conducted by the Boeing Airplane Company for the U.S. Air Force just after World War II. The first version of GAPA was a bi-propellant type about 10 feet long with four tail fins. The motor was made by Aerojet. Take-off was assisted by a solid RATO. First firing was from the Great Salt Desert, Utah. In 1948, the GAPA project concentrated on a ramjet propulsion system for a missile of approximately 5,000 pounds, aiming toward a velocity of 2,750 feet per second. The research of this project was later applied by Boeing to the development of their BOMARC interceptor missile.

GAR. Guided Aircraft Rocket.

GAR-1, 2, 3, 4. Falcon.

GAR-8. Sidewinder.

GARGOYLE. A McDonnell Aircraft Corporation missile designed for air-to-surface use. It had a thick short body with stubby wings and a "V"-type tail. It was radio-controlled and propelled by a liquid rocket engine, at a top speed of some 600 miles per hour. Payload was 1000 pounds. Although developed during the latter part of the Second World War, the missile was never used during combat. Its dimensions were: length 10 feet, wingspan 8½ feet. Its configuration was similar to a low wing monoplane with a "V" tail. Guidance was by radio command. Range was about 5 miles. It was also identified as the KUD-1 and KSD-1.

GAS CONSTANT. Equation of state.

GAS DISCHARGE TUBE. An **electron tube** in which the pressure of the contained gas or vapor is such as to affect substantially the electrical characteristics of the tube.

GAS GENERATOR. Generator, gas.

GAS MISALIGNMENT. Non-uniform flow of gas through the nozzles of a rocket.

GAS TURBINE. In the gas turbine a stationary nozzle discharges a jet of gas (usually products of combustion) against the blades on the periphery of a turbine wheel. The jet is

thereby deflected and slowed while the blades receive an impulse force which is transmitted as a mechanical torque to the shaft. The prospective jet speed is sometimes sufficiently high to warrant dividing the expansion into a series of *stages* with a set of nozzles and a row of blades in each stage, all blade wheels being mounted on the same shaft. By limiting the gas expansion per stage the blade speed and rpm of the shaft are suitably decreased. Were the blades themselves so shaped as to be virtual nozzles, some expansion would also take place in the gas as it went through the blading. The latter in consequence would receive a "reaction thrust" distinct from impulse action. Many gas turbine designs have employed the reaction principle.

A properly designed nozzle can produce almost an ideal (isentropic) adiabatic expansion of the gas. Any failure of the gas turbine to convert all the ideal available energy into work at the shaft is mainly attributable to the blading—its clearance, friction, leakage, and residual gas velocity.

GAS TURBINE ENGINE. A power plant or engine that utilizes a **gas turbine** to generate mechanical power, especially to rotate the compressor in a jet engine or to rotate certain accessories or generators used in a jet aircraft.

GASLIGHT. A U.S. Army Ordnance program to determine the re-entry radiation spectral and intensity characteristics of the **JUPITER** IRBM nose cone. The measuring program was conducted in 1958 by the Barnes Engineering Co., under contract with the Army Ballistic Missile Agency.

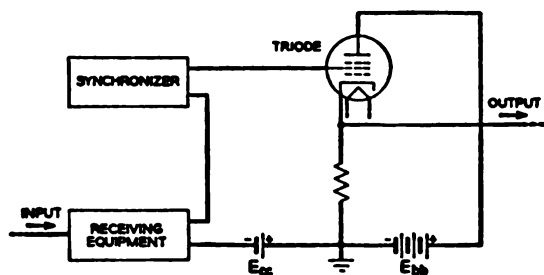
GAT. Greenwich Apparent Time.

GATE. (1) A circuit having an output and a multiplicity of inputs so designed that the output is energized when and only when a certain definite set of input conditions are met. In computer work, a gate is often called an "and" circuit. (2) A signal used to enable the passage of other signals through a circuit. (3) That part of a saturable reactor which exhibits **thyatron** or **gate action**. (4) A range of air-fuel ratios in which combustion can be initiated.

GATE ANGLE (FIRING ANGLE). The angle at which the **gate impedance** changes

from a high to a low value. This angle is also called the firing angle.

GATE CIRCUIT. A circuit which amplifies or passes a signal only in the presence of an appropriate synchronizing or "gating" pulse which "opens the gate." The following circuit is a simplified example of one form which gating circuits may take:



Simplified drawing of gate circuit.

In this circuit, pulses from the receiving equipment are combined with rectangular pulses from the synchronizer, and impressed upon the grid of a triode, along with a negative, biasing voltage. Pulses from the synchronizer are of positive-polarity, and sufficiently large to cause the triode to operate in its linear mode when they are present. When synchronizing pulses are absent, the triode is cut off, and the output is zero.

top which does not descend, and its stem passes through a packing gland.

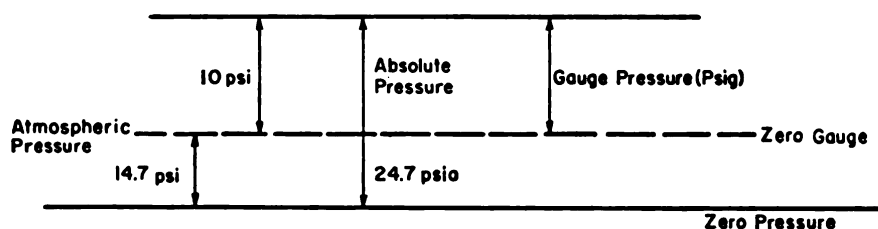
GATE WINDING. The winding of a saturable reactor which produces the "on-off" action on the load current.

GATING. (1) The process of selecting those portions of a wave which exist during one or more selected time-intervals, or which have magnitudes between selected limits. (2) The function or operation of a saturable reactor or magnetic amplifier which causes it, during the first portion of the conducting alteration of the a-c supply voltage, to block substantially all of the supply voltage from the load; and during latter portion allows substantially all of the supply voltage to appear across the load; is called gating or gating action. The "gate" is said to be virtually closed before firing and substantially open after firing.

GATING CIRCUIT. A time-selection transducer. (See **transducer, time-selection**.)

GATING WAVEFORM. A waveform (sometimes called the "gate") applied to the control point of a circuit in such a way as to alter the mode of operating of the circuit while the waveform is applied.

GAUGE PRESSURE. Pressure above the pressure of the atmosphere. (See figure.)



Pressure relationships.

Several gate circuits may merge into the load; the latter circuit is then called the load circuit, and the total current flowing through the load is called the load current.

GATE IMPEDANCE. The impedance of one gate winding.

GATE, TIME. Time gate.

GATE VALVE. A valve having as its major functional part a gate or disc, which is screwed down between two machined faces, or seats. The gate is operated by a wheel

GAUSS. The emu unit of magnetic induction (flux density), one maxwell per square centimeter.

GAUSSIAN DISTRIBUTION. A normal distribution.

GAY-LUSSAC LAW(S) OF. (1) (Law of Volumes, Law of Charles) The volume of a gas held at constant pressure varies directly as the absolute temperature. This law holds only for the ideal or perfect gas; all real gases depart from it to a greater or less extent. This law is also known as the Law of

Charles. (2) In all reactions involving gases, either as initial reactants or as products, or both, the proportions by volume of the gaseous substances can be expressed accurately by ratios of small whole numbers.

GB. An Army Air Corps (World War II) designation for the Glide Bomb. A series of these weapons were developed during World War II running from *GB-1* through *GB-15*.

GBL. Government Bill of Lading.

GC. Ground Control; Grand Central Rocket Company, Redlands, California.

GCA. Ground-controlled approach.

GCC. Ground Control Center.

GCI. Ground Control Interception. GCI is any of several systems involving radar tracking for the directing of fighter interceptor aircraft to the vicinity of hostile or unknown targets. The radar equipment tracks both the hostile and the friendly aircraft; thereafter the interceptor is "vectored" to the target by radio commands.

GCR. Ground Controlled Radar.

GCT. Greenwich Civil Time.

Gd. Gadolinium.

Ge. Germanium.

GE HEAVY MIL ELEC. General Electric Heavy Military Electronics Division; Syracuse, New York.

GE LIGHT MIL ELEC. General Electric Light Military Electronics Division; Philadelphia, Pennsylvania.

GEAR PUMP. A positive displacement pump suitable for liquids of high viscosity under high differential pressures. Clearances are close and gears are likely to gall unless non-galling alloys are used. This limits the use of gear pumps to certain fluids. Gear pumps operate at pressures in the vicinity of 500 psi and are practical when the viscosity exceeds 10 centistokes, when the volume of flow exceeds 25 gallons per minute, and when the fluid is non-corrosive. Gear pumps normally operate in the neighborhood of 2000 rpm.

GEE. A system of medium-range hyperbolic radio navigation based on comparison of time of receipt of two transmitted pulses; one pulse from a master radio station and the other from a "slave" station which transmits simultaneously with the master, but is triggered by the master pulse. Position lines are determined by measuring the time difference of the arrival at the ship or aircraft of the synchronized signal pulses. (See also **LORAN**; **Navigation**.)

GEIGER COUNTER. (1) A radiation counter designed to operate in the **Geiger region**. (2) A radiation counter having a point or small sphere as its central electrode. This usage is obsolescent. (See **counter**, **point**.)

GEIGER REGION OF A RADIATION COUNTER TUBE. (See **plateau characteristic**.) The range of applied voltage in which the charge collected per isolated count is substantially independent of the nature of the **initial ionizing event**.

GEIGER THRESHOLD OF A RADIATION COUNTER TUBE. The lowest applied voltage at which the charge collected per isolated tube count is substantially independent of the nature of the **initial ionizing event**.

GEL. A two-component colloidal system of a semi-solid nature, rich in liquid. The gelling component is usually of the lyophilic type and present in concentrations less than about 10 per cent. The gel, or semi-solid form of a colloidal system, is related to the **sol**, or liquid form, in that they are usually mutually transformable.

GEMINI. (The twins.) This **constellation**, which marks the third sign of the zodiac, has been recognized as a pair of twins from remote antiquity.

GENERAL OPERATIONAL REQUIREMENT (GOR). The initial requirements established by the Military Services for a weapon system. These represent the boundary conditions for the preliminary design.

GENERATOR, ELECTRICAL. A mechanical device for the production of electricity consisting of a rotating part surrounded by a fixed part. The relative motion between the two, produced by a prime mover, moves a

series of conductors so as to cut a magnetic field or *vice versa*, to induce electrical voltages, and thus to cause current to flow in an external circuit. The primary purpose of the generator may be to transfer power from the point of generation to points on the external circuit; to transform it from mechanical, hydraulic, chemical or nuclear form to electrical form; or to effect one of various other purposes. Thus, a signal generator is used to actuate a radio or a radar antenna.

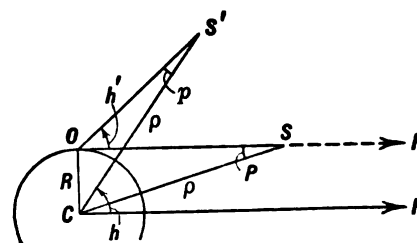
GENERATOR, GAS. A combustion chamber used to provide hot gases for a turbine to drive the propellant pumps of a rocket engine. Gas generators are usually operated fuel rich.

GENIE. A U.S. Air Defense Command air-to-air missile manufactured by Douglas Aircraft. It carries a nuclear warhead, and is powered by an Aerojet-General rocket. It was developed by the Air Research and Development Command for air defense. It became operation January 1957, launched by F-89 J in Operation Plumbob, July 1957, at Nevada test site. It was formerly called Ding-dong. (See **missile, guided**.)

GEOCENTER. The center of mass of the earth. It is always one focus of an earth-bound elliptical missile trajectory. Geocentric measurements, such as latitude, are taken from the center of the earth. The coordinates published in an ephemeris or almanac are generally geocentric. Geocentric latitudes are not exactly the same as geographical latitudes, due to the slightly non-spherical figure of the earth.

GEOCENTRIC COORDINATES. Any system of coordinates on the celestial sphere which uses for its origin, or reference point, the center of the earth is known as a system of geocentric coordinates. Practically all coordinates published in an ephemeris or almanac are geocentric in character.

GEOCENTRIC PARALLAX. The origin of the apparent systems of spherical coordinates is a point on the surface of the earth, while the origin of the geocentric systems is at the center of the earth. For obvious reasons, all observations must be taken in the apparent system. For the solution of most problems, geocentric coordinates are desired. The trans-



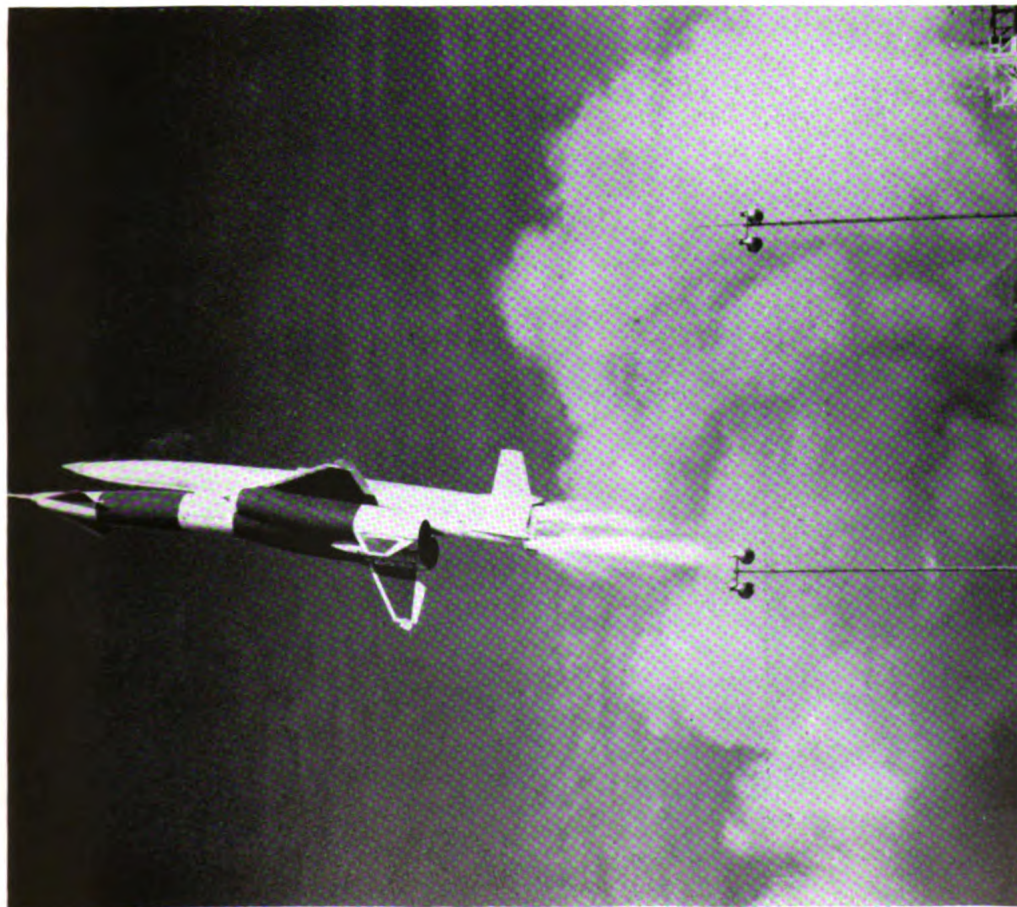
Geocentric parallax in altitude.

fer from one system to the other is made by applying a correction for geocentric **parallax**.

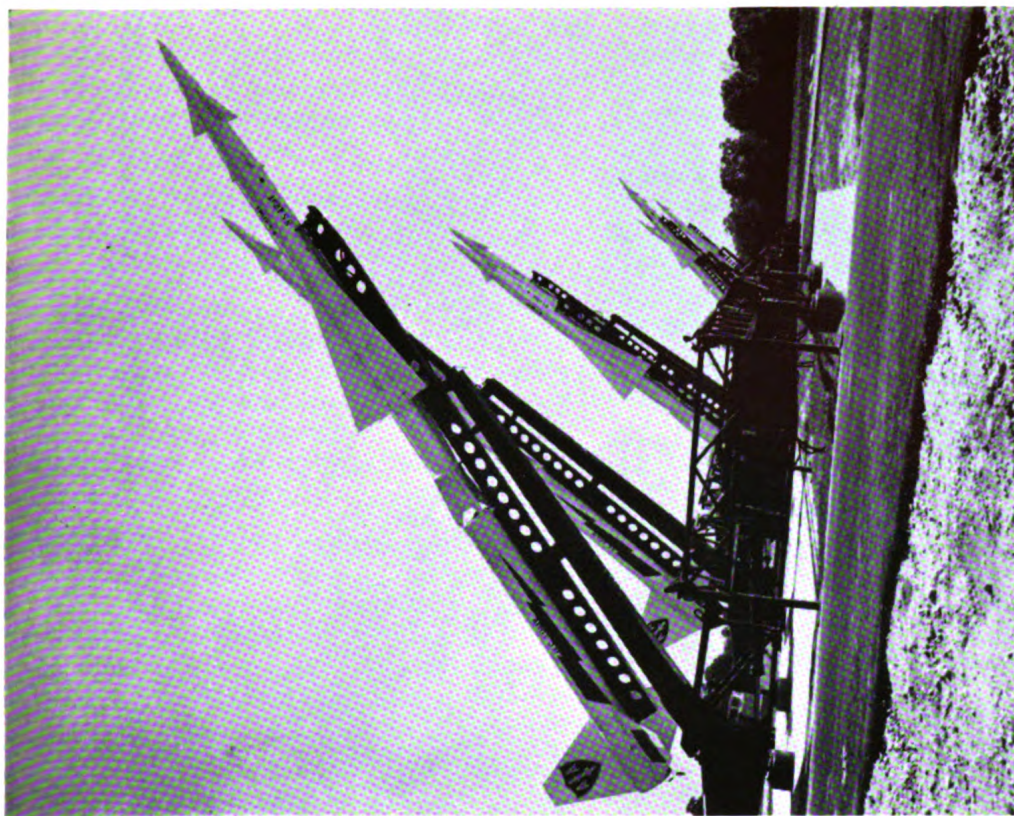
In the figure we have C the center of the earth of radius R , and O the position of an observer on the surface. OC is the direction of gravity at O . OH is the direction of the astronomical horizon and CH is a parallel direction drawn through the center of the earth. S and S' represent two positions of an object at distance ρ from the center of the earth, S being the position when the object is on the horizon. At S' the object has an apparent altitude h' and a geocentric altitude h . P is defined as the horizontal parallax of the object and is the angle subtended at the object by the radius of the earth. For rigor the quantity usually defined is the mean equatorial horizontal parallax which is the angle subtended by an equatorial radius of the earth at the object, when the object is on the horizon, and at its mean, or average, distance from the earth. The equatorial horizontal parallax is tabulated in **Ephemerides** for all members of the solar system for selected dates. Inspection of the figure indicates that $\sin P = R/\rho$.

The geocentric altitude h is greater than the apparent altitude h' by the angle p which is defined as the geocentric parallax in altitude. In the oblique plane triangle COS' we have $\frac{R}{\rho} = \frac{\sin p}{\cos h'}$ but we have already seen that $R/\rho = \sin P$ whence $\sin P \cos h' = \sin p$. Now both P and p are such small angles that, without sensible errors for most problems, except those dealing with the moon, we have $p = P \cos h'$ giving the geocentric parallax in altitude in terms of the equatorial horizontal parallax and the apparent altitude of the object. For objects outside of the solar system the value of P is far too small to be appreciable in even the most refined observations.

In case other spherical coordinates than altitude are to be used, the geocentric parallax in altitude may be transformed to the



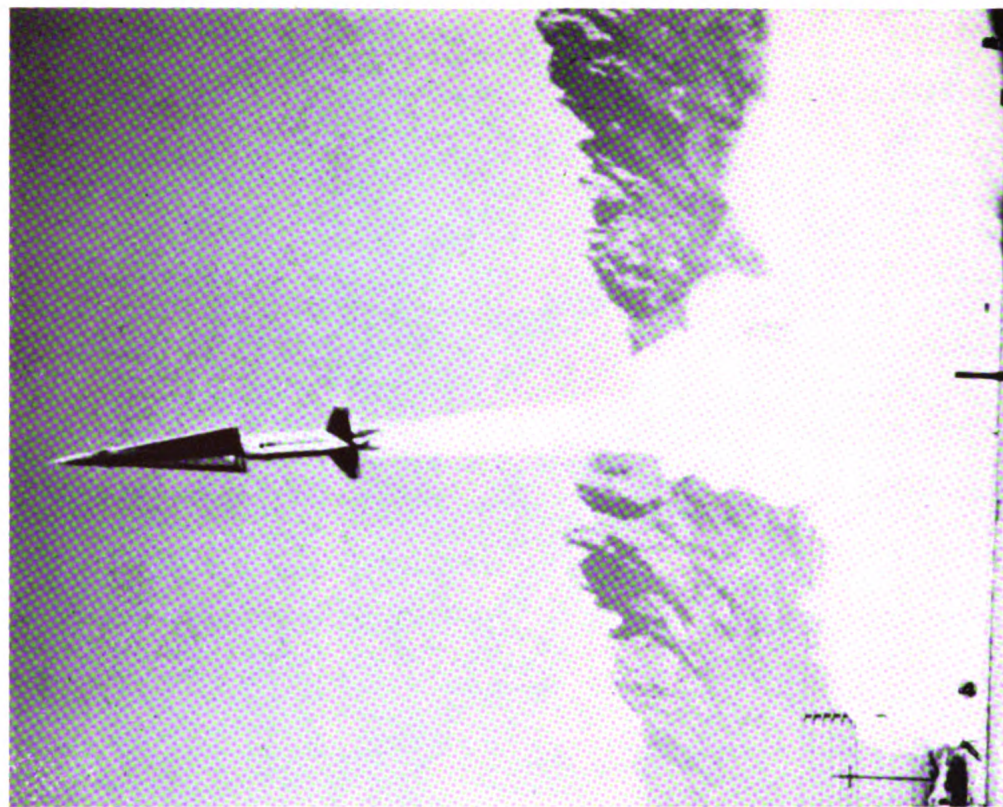
The NAVAHQ, a long-range surface-to-surface guided missile developed for the Air Force by North American Aviation. The missile is shown here being launched at the Air Force Missile Test Center, Cape Canaveral, Florida, where tests of components continued until expended in support of other more advanced programs. (*U.S. Air Force Photograph*)



NIKE guided missiles at varying degrees of elevation, at Nike Site, Lorton, Virginia. May 16, 1955. (*U.S. Army Photograph*)



The NIKE-CAJON (Dan Missile). August 7, 1956. (*U.S. Army Photograph*)



The NIKE-HERCULES, the U.S. Army's surface-to-air guided missile, in flight. January, 1957. (*U.S. Army Photograph*)

desired quantities by solution of the **astronomical triangle** or other triangles on the **celestial sphere**.

GEODESIC. The shortest line on the surface of the earth between two points.

GEODESY. The science involving the dimensions of the earth. It includes determination of the size and figure of the geoid, gravity measurements, magnetic field measurements or any other physical quantities that exist as characteristics of the earth. Geodetic surveying is the process of determining the size and figure of the earth.

GEODETIC. (1) Of or pertaining to the earth and its measurements. (2) In airframe construction, a geodetic construction is a lattice-work or basket weave type of structure based upon the principle that a great circle provides the greatest strength.

GEOGRAPHICAL COORDINATES. Geographical coordinates provide a method for determining the position of a point on the surface of the earth by means of a system of **spherical coordinates**. Because of the fact that the earth is not a sphere but is in reality an oblate spheroid, technically the system of coordinates cannot be strictly spherical. The geographical method of representation of the position of points on a spherical earth by means of **latitude** and **longitude** was first applied by Ptolemy in the construction of his atlas of the world during the second century of the Christian era.

GEOID. In geodesy, the surface of equal gravity through mean sea level. It is the figure of the earth considered as a mean sea level surface extended continuously through the continents. It is not the actual surface of the earth. The reference spheroid is the spheroid obtained by revolving an ellipse about its shorter (polar) axis, and it is used as a base for geodetic surveys by many countries in the same way as the Clarke Spheroid of 1866 is used for geodetic surveys in the United States.

GEOPHYSICAL CONSTANT. A constant term appearing in a relationship in **geophysics**, e.g., the constant of gravitation or the constant of nutation.

GEOPHYSICS. The study dealing with all the physical aspects of the earth, including

meteorology, geodesy, terrestrial magnetism, gravity, etc., etc.

GEOPOTENTIAL. The increase in potential energy per unit mass lifted from mean sea level to a given point against the force of gravity. One standard geopotential meter is the vertical distance through which one **kilogram** mass must be lifted against the force of gravity to increase its potential energy by 9.80665 joules.

GEOPHONE. A small seismometer responding to actual displacement of the surface of the earth (or bottom of the ocean) used for detection of vibrations due to geodetic quakes or, in military applications, to large sounds.

GEOREF GRID. The grid used on USAF aeronautical charts for identifying the location of any point or area in the world; the system involved in the use of this grid. Formerly World Geographic Grid. By this system the world chart is divided into 24 parallel north-south strips 15° wide numbered from A through Z (I and O omitted), beginning at the South Pole. Each quadrangle is subdivided into 15 lettered units eastward and 15 lettered units northward. These are lettered from A through Q (P and O omitted). Each one degree quadrangle is subdivided into 60 numbered minute units. Minute units may be subdivided further into decimal parts.

GEOSTROPHIC WIND. The wind that is the result of a balanced pressure gradient and **Coriolis force**. Geostrophic winds blow in straight or nearly straight lines. Low pressure is to the left of the wind direction in the northern hemisphere when the observer stands with back to the wind.

GERMANIUM. Metallic element. Symbol Ge. Atomic Number 32.

GETTER. A metallic deposit in a vacuum tube whose function is to absorb residual gas. The best getters are the electropositive metals such as sodium, potassium, magnesium, calcium, strontium, and barium.

GF. Aviation Guided Missile.

GFAE. Government-Furnished Airborne Equipment.

GFE. Government Furnished Equipment.

GFM. Government Furnished Material.

GFP. Government Furnished Property.

GHA. Greenwich hour angle.

GHOST(S). (1) In spectroscopy, false images of a spectral line produced by irregularities in the ruling of diffraction gratings. Rowland ghosts are false images grouped symmetrically on both sides of the true line. Lyman ghosts are false orders of spectra for which the **order** is not an integer. (2) In television or radar, the spurious image resulting from an echo, as from multiple transmission paths.

GIANT AND DWARF STARS. With the absolute **magnitudes** and **spectral classes** of a number of stars known, a diagram may be plotted showing absolute magnitudes as ordinates against spectral classes as abscissae. Such a diagram was first published by Russell of Princeton in 1913. He found a number of stars of approximately the same absolute magnitude running as a horizontal line across the top of the diagram and a series of stars of progressively decreasing absolute magnitude with spectral class changing from B to M. From the shape of the original diagram it became known as the "figure 7 diagram." In 1905, Hertzsprung noticed that there was a sharp distinction between M-type stars of high and low luminosity and he referred to them as giant and dwarf stars. With the publication of the figure 7 diagram it became evident that the distinction between giant and dwarf classification could be extended to all spectral classes. However, the difference between the giant and dwarfs becomes less and less striking as we proceed from the M-type stars toward the B-types.

The stars of globular clusters belong to a type of stellar population considerably different from that in the sun's neighborhood. Although the difference had been recognized for some time, interest in the matter was not fully awakened until 1944, when W. Baade of Mount Wilson Observatory showed that the clusters are not unique in this respect. Baade designates the two populations as types I and II.

GILBERT. The unit of **magnetomotive force** in the emu system. One gilbert = $10/4\pi$ ampere turns. (See **units and dimensions**.)

GIMBAL. A mechanical frame containing two mutually perpendicular intersecting axes of rotation. It is often used as a mechanical mount for a **gyroscope**. It contains two mutually perpendicular intersecting axes of rotation allowing free movement through 360 degrees in the plane of each axis. By means of the gimbal mounting a gyroscope is given three degrees of freedom so that it can pick its own space orientation.

GIMBAL LOCK. Catastrophic malfunction of a two-axis gyroscope in which the normally orthogonal gimbals become aligned, i.e., the precession angle θ reaches 90° ; usually results from excessive angular motion of the missile.

GIMBALED MOTOR. A **rocket** motor mounted on a gimbal, i.e., on a contrivance having two mutually perpendicular and intersecting axes of rotation so as to obtain pitching and yawing correction moments.

GIMMICK. The colloquial name given to a small **capacitor** (1-5 micromicrofarads) formed from two insulated wires twisted together.

GISEMENT. In map reading, the angle between geographic north and grid north. It is also called (more commonly) grid declination.

G_L. Local gravitation acceleration.

GLANCING ANGLE. (1) The angle between a ray and the tangent plane to a surface. The complement of the **angle of incidence**. (2) The term is often used as a modifier, to indicate the incidence of a beam at a very small angle with the surface.

GLAND. A sealing device included in junctions between two components of a machine carrying a working fluid. The gland permits motion of adjoining parts but prevents leakage of the working fluid.

GLAUERT FACTOR. In aerodynamics, between Mach 0.6 and 0.86, there is an increase in the lift of certain configurations of airfoils. This is due to the compressibility effects of high speed which begin to be felt in this speed region. This increase varies according to the relationship:

$$C_{L \text{ compressible}} = (C_{L \text{ incompressible}}) (1 - M^2)^{-1/2}$$

where C_L is the coefficient of lift and the ex-

pression $(1 - M^2)^{-\frac{1}{2}}$ is called the Glauert Factor and represents the increase in lift coefficient due to compressibility. The Glauert effect is beneficial because it gives better lift for the same wing incidence and same profile-drag coefficient. This is a theoretical concept, however, assuming two-dimensional flow over a surface. A wing of finite dimensions has tip vortices which can change the relationship. (See also **Compressibility** and **Karman-Tsien Relation**.) The following are some values of the Glauert Factor for infinite aspect ratio:

M	$(1 - M^2)^{-\frac{1}{2}}$	M	$(1 - M^2)^{-\frac{1}{2}}$
0	1	0.60	1.2500
0.1	1.0050	0.70	1.4003
0.20	1.0206	0.80	1.667
0.30	1.0483	0.90	2.2942
0.40	1.0911	1.0	∞
0.50	1.1547		

GLAUERT LAW. Is an expression of the Glauert effect in differential form:

$$\left(\frac{dC_L}{d\alpha}\right)_{\text{compressible}} = \left(\frac{dC_L}{d\alpha}\right)_{\text{incompressible}} (1 - M^2)^{-\frac{1}{2}}$$

where C_L is the coefficient of lift, α is the angle of attack, and M is the Mach number.

GLIDE. The descent or drop of an aircraft or winged missile at a normal or nearly normal angle of attack, with little or no thrust.

GLIDE ANGLE. The acute angle between the glide path and the horizontal.

GLIDE BOMB. A winged missile powered by gravity. The wing loading is so high that it is incapable of flight at the speeds of modern bombardment aircraft. Such a missile therefore must be carried rather than towed. Glide bombs are often remotely controlled, and sometimes have power plants to give initial thrust or to extend the glide.

GLIDE PATH. The flight path of an aircraft or winged missile as it glides downward.

GLIDE RATIO. The lift to drag ratio (C_L/C_D).

GLIDER. (1) A fixed-wing airplane having no power plant, and constructed so as to glide and soar. (2) A recoverable, reentry satellite,

so shaped as to utilize the resistance of the atmosphere to minimize the shock of landing after reentry. Two models of such vehicles have recently been released by the National Advisory Committee for Aeronautics, a delta-wing type and a boat-shaped type. (See illustrations facing Page 538.) These satellites reenter the atmosphere at a high angle of attack (about 55°) so as to gain as much lift as possible and to minimize aerodynamic heating. They are insulated to carry a man.

GLINT. The pulse-to-pulse variation in amplitude and apparent origin of reflected radar signals, owing to the reflection of the radar beam from a body which is changing its reflecting surface in an extremely rapid manner, such as would exist in pulses reflected from a rapidly spinning airplane propeller.

GLOBOID. An ellipsoid of revolution resembling the shape of the earth. Synonymous with **geoid**.

GLOMB. A contraction of the words **glide bomb**.

GLOW PLUG. An electric heating element which is used to raise a rocket propellant to its autoignition temperature.

GLYCERIN. An organic chemical compound of composition $C_3H_5(OH)_3$. It is used as an antifreeze compound because of its low freezing point.

GLYCEROL TRINITRATE. Commonly called nitroglycerin, an organic explosive having the chemical formula, $C_3H_5(ONO_2)_3$. It is commonly used as a **propellant** for solid-propellant rockets. (See **Ballistite**.)

g_m . Designation for the mutual conductance of a vacuum tube.

GM. Guided Missile.

GMT. Greenwich Mean Time.

GNOMONIC PROJECTION. A portrayal of the earth's surface in which the meridians and parallels of latitude are projected to a plane tangent to the earth at one point: e.g., north pole. Meridians appear as straight lines converging toward the pole and parallels of latitude are not parallel. Distortion increases with distance from the tangent point.

Neither distance nor direction can be measured directly but great circles plot as straight lines. For this reason it is sometimes called a great circle chart and used for nautical navigation.

g. Standard gravitational acceleration.

GO, NO-GO DETECTOR. An instrument which has only two stable states of indication, and which therefore will give full response to any stimulus capable of actuating it. For example, a common fuse is a go, no-go detector, since either it is intact, or it is burned out. An ammeter, however, can respond continuously to the same current.

GOLD. Metallic element. Symbol Au. Atomic Number 79.

GONIOMETER. (1) An instrument for measuring the angles between the reflecting surfaces of a crystal or a prism. (2) A radio receiver and directional antenna system for determining the angle of arrival of incident waves. (3) An Autosyn phase shifter driven by a common gear train.

GOOSE. A surface-to-surface diversionary missile under development by the Fairchild Engine and Airplane Company for the Strategic Air Command. Its range is believed to be over 500 miles. It is designed to help penetrate enemy defenses in case of hostilities. (See illustration facing Page 154.) It was formerly called the Bull Goose.

GOR. General operational requirements.

GORE. A triangular portion of fabric between two seams or shroud lines in a parachute or balloon.

GORGON. A U.S. Navy series of missiles considered for air-to-air, air-to-surface, and surface-to-surface use. Development of these was carried out during World War II at the Engineering Experimental Station at Annapolis, Maryland (rocket engine), and the Naval Aircraft Factory at Philadelphia, Pennsylvania (airframe). Neither of the two principal Gorgon types were used during hostilities. Gorgon II-A was an air-to-air missile intended to be launched from a PB4Y-2 aircraft. It used a nitric-sulfuric acid mixture as oxidizer, and a monoethylaniline fuel to drive a small 10-pound motor which developed

a thrust of 350 pounds. The missile had a slim cigar-shaped fuselage with a single wing far back on its body. The tail assembly was separated with the vertical stabilizer extending symmetrically above and below the fuselage. The rudder was on the bottom fin. The horizontal stabilizer was forward near the nose in a canard configuration. The missile could operate in an inverted, as well as a normal position. Guidance was by radio command, with a television monitoring link. This missile attained 730 feet per second velocity during a two-minute burning time and is believed to be the first U.S. rocket powered guided missile.

Georgon IV (also designated PTV-N-2), was a ramjet test vehicle intended for either air or surface launching. It weighed about 1,600 pounds, 700 pounds of which was fuel (80-octane gasoline); its length was 22 feet and its wingspan, 10 feet. Launching was by air drop or catapult from the deck of a ship. Its power plant was a 20-inch Marquardt ramjet, hung beneath the fuselage. Parachute recovery was provided. It was built by the Martin Company; as a target drone, it was called the Plover or KDM-1.

GOX. Gaseous oxygen.

GRAD. A unit of angular measure, defined as the angle subtended by an arc of $1/400$ of a circle. Therefore, 100 grad is equal to 90 degrees. The grad is divided into 100 centesimal minutes, and the centesimal minute is divided into 100 centesimal seconds. Centesimal minutes and seconds are designated by the conventional symbols set in reverse inclination; thus 5 centesimal minutes is written 5' and 10 centesimal seconds is written 10".

GRADIENT. In general, an incline or slope, hence a range of values, either descending or ascending. A pressure gradient is a continuous increase or decrease of intermediate values, between two points at different pressure. The term is applied also to other physical quantities, expressed as temperature gradient, velocity gradient, or even elevation gradient, although the latter usage is prolix.

GRADIENT WIND. A wind that blows parallel to curved isobars in a field of unchanging pressure. Thus, a gradient wind blows when the pressure gradient, Coriolis force, and centrifugal force are balanced, and

when there is no acceleration. In clockwise systems in the northern hemisphere Coriolis force balances both centrifugal force and the pressure gradient; in the counterclockwise system, the pressure gradient balances both centrifugal force and Coriolis force.

GRAIN. A mass of solid propellant, which has been cast or extruded in a single piece, or which has been produced in that form by cementing or compressing smaller particles. The term arises from the fact that the early propellants were double-base materials molded into uniform particles. In ordnance terminology, a single particle of propellant powder is called a grain, regardless of its size, which can vary from 0.01 inch to several inches. This usage extends to solid propellants for rockets or missiles, where a grain may have a size of several feet (in one of its dimensions, at least). Such grains are often pierced with longitudinal holes, or are extruded into regular geometrical cross-sections, to produce more uniform burning. The structure of a grain has considerable influence on its behavior during combustion. In some instances, rapid burning of a long slender grain gives rise to sound vibrations which crack its structure before combustion is complete, causing that process to be irregular, or even explosive. This condition can be prevented by various methods, including suitable design of the grain-shape or the use of anti-resonant devices to change the sonic response during combustion.

GRAIN, CASE BONDED. In solid rocket usage, a grain cemented or bonded to the case or container to prevent burning on the surface adjacent to the container.

GRAIN, RESTRICTED BURNING. Restricted burning grain.

GRAIN, STAR. Star grain.

GRAM. (1) A unit of mass, abbreviation gm or gr. One one-thousandth of a kilogram. (2) A unit of force, abbreviation gf or gr. The weight of a gram mass at the earth's surface. If greater precision is needed, it is specified that this weight should be measured at a point where the acceleration due to gravity is 980.665 cm/sec².

GRAM-ATOM. That quantity of an element having a mass in grams numerically equal

to the **atomic weight**. One gram atom contains the **Avogadro number** of atoms.

GRAM-ATOMIC WEIGHT. The weight of a gram-atom.

GRAM-MOLECULAR WEIGHT. That amount of a pure substance having a weight in grams numerically equal to the **molecular weight**. One gram-molecular weight contains the **Avogadro number** of molecules. It is also designated as the mole or mol.

GRAM-RAD. A unit of integral absorbed dose, recommended by the International Commission on Radiological Units (July, 1953). It is 100 ergs.

GRAPH. A line drawing expressing a relation between two variables; or more generally, any record produced by physical methods.

GRASHOF'S NUMBER. A dimensionless parameter defined as follows:

$$G = \frac{\beta \theta g L^2 \rho^2}{\mu^2}$$

Where G is the Grashof number, β is the thermal expansion coefficient, θ is absolute temperature, g is gravitational acceleration, L is the length, ρ is the density, and μ is the coefficient of viscosity.

GRASS. The pattern on the **cathode-ray tube** display of a radar or similar system, which is produced by the random noise output of the receiver.

GRAVICS. The science dealing with gravitational fields in all their aspects.

GRAVIRECEPTOR. A nerve ending that responds to a mechanical stimulation incident to gravity.

GRAVISPHERE. The spherical region in which the gravitational force of a given celestial body is predominant.

GRAVITATION AND GRAVITY. The distinction between these two terms is that between a universal property of matter and the special manifestation of that property exhibited in the vicinity of the **earth** or other celestial attracting mass and modified by the **centrifugal force** of planetary rotation.

Newton's conception of gravitation was expressed by his statement, to the effect that

every particle of matter attracts every other particle with a force proportional to the product of the masses and to the inverse square of the distance. We are thus left to picture an infinitely complex network of attractions joining every two particles in the universe and tending to pull them together. Newton did not specify what the "particles" were assumed to be, whether atoms or otherwise. Faraday introduced a somewhat different picture in the form of a stressed medium, with its curved lines and tubes of force. The Einstein concept, again, envisages a space so warped by the presence of surrounding masses that a particle, which if projected into an empty space would follow a straight line, actually follows a more or less complicated curve, a geodesic line of this warped space, which represents physically the most direct path between any two points of the space. Furthermore, **Einstein's equivalence principle** makes no distinction between gravitation and centrifugal force.

The Newtonian law may be expressed by the equation $f = Gm_1m_2/r^2$, in which m_1 and m_2 are the masses of two particles, r the distance between them, and G the **gravitation constant**. For practical purposes the "particles" may be homogeneous spheres, r being the distance between their centers. Other bodies of finite size, such as cubes or cylinders, would not do, as they are not "centrobaric"; that is, there is no one point toward which their attraction is directed. The planets and stars being sensibly spherical, they may be treated approximately as particles. It was from the study of the **two-body problem** as applied to such objects that Newton deduced the conclusion expressed in his law.

For the magnitude of the gravitational acceleration at the earth's surface, the internationally adopted standard value is 980.665 centimeters per second per second, or 32.1740 feet per second per second. This value varies considerably over the surface of the earth because of the following effects: (1) centrifugal force of the rotating earth, which is greatest at the equator, (2) irregularities in the **figure of the earth** and (3) variations in density throughout the earth. The first of these effects has as one of its consequences, variations in gravitational acceleration with latitude. The gravitational acceleration is a maximum at the poles (where the earth's surface is closer to the center of mass of the

earth), and decreases toward the equator. The nominal value of the gravitational acceleration at the poles is 983.223 cm/sec² (32.25797 ft/sec²), which decreases to 978.046 cm/sec², at the equator. This decrease is due essentially to the fact that the distance of the center of the earth is less at the equator than at the poles, and so the force decreases in accordance with the Newtonian law cited above. This law also gives a formula for determining the gravitational acceleration of the earth at any point above its surface, as follows:

$$g_h = g_e \left(\frac{R_e}{R_e + h} \right)^2$$

Where g_h is the gravitational acceleration at h altitude, g_e is that at the surface of the earth, R_e is the radius of the earth, and h is the altitude above the surface of the earth. As stated above, the gravitational acceleration also varies with latitude, being the resultant of the attraction of the earth for a body, and the centrifugal acceleration due to the earth's rotation, as given by the relationship:

$$g_\phi = g_e \left[1 + \frac{g_p - g_e}{g_e} \right] \sin^2 \phi.$$

where g_e is the value at the equator, g_p , that at the poles, and g_ϕ that at the given latitude.

Irregularities in density throughout the earth affect particularly the direction in which the gravitational force is exerted, i.e., the direction of the acceleration vector. Its anomalies normally do not exceed 10 seconds of arc, but where island masses are bounded by deep water (e.g., Puerto Rico), errors as high as one part in 50 can result in deflections of a plumb line from readings taken at points on opposite coasts of the island. The value of the gravitational acceleration is of great interest in missile applications where inertial guidance (see **guidance, inertial**) systems are used. The variations in gravitational acceleration with altitude, latitude and other effects can change the path of a missile unless the guidance scheme is such as to eliminate the influence of the gravitational force. If the guidance system has a stabilized platform using the local vertical for a reference established at the beginning of flight, and then travels for long periods over areas of non-parallel and unequal gravitational attraction, it must be monitored to correct for these errors. The effect of gravitational anomalies is

not so significant with **ballistic missiles**, since inertially-guided missiles of this type determine their impact point relatively early in their trajectories, traveling nearly straight upward during their powered flight.

As is seen from the Newtonian law, the gravitational force exerted by a body is directly proportional to its mass. This fact, together with the inverse square relationship for distance, is the basis for computing the effect upon missile or space ship trajectories of bodies other than the earth. For such data, see **planet** and **satellite**.

GRAVITATIONAL ANOMALIES. Irregularities in the distribution of the **gravitational field** of the earth over its surface.

GRAVITATIONAL FLATTENING. The constant

$$\frac{g_p - g_e}{g_e}$$

where g_p is the gravitational acceleration at the poles, and g_e is the gravitational acceleration at the equator. This constant occurs in the formula for finding the value of the **gravitational acceleration** at a given latitude.

GRAVITATIONAL SLOPE. The uniform decrease of gravitational attraction with increasing distance between bodies, or its converse.

GRAVITY (NON-ROTATING EARTH). The acceleration force exerted on terrestrial bodies by a fictitious earth which is homogeneous, stationary, isolated, and spherical.

GRAVITY TILT PROGRAM. A theoretical missile trajectory involving a flight program in which there is no lift due to **angle of attack** (i.e., angle of attack is zero). The missile is tilted with respect to the relative wind to maintain a zero angle of attack; hence it experiences no aerodynamic lift and responds only to the forces of gravity.

GRAY BODY. A radiator whose spectral emissivity remains constant through the spectrum, being in a constant ratio, less than unity, to that of a complete radiator (**black body**) at the same temperature.

GRAY CODE. A modified binary code used for analog-to-digital conversion. The principle of operation is based on the change of only

one element in a system at a time when passing from one digit to the next. It is also called a cyclic binary or reflective code.

GRAYOUT. A temporary condition, incident to prolonged acceleration, in which vision is hazy, restricted, or otherwise impaired, owing to insufficient oxygen in the head (Cf. **black-out**.)

GREAT CIRCLE. (1) A circle on the surface of a sphere, the plane of which passes through the center of the sphere and divides it into two equal parts. (2) Such a circle on the surface of the earth.

GREAT CIRCLE COURSE. The shortest path between two points on a spherical earth. The path is coincident with the circular arc whose radius is equal to that of the earth, and whose center of curvature is located at the center of the earth. The great circle distance between two points not at sea level is taken as the great circle distance between the vertical projections of the two points upon the sea level surface.

GREAT CIRCLE DISTANCE. Great circle course.

GREEN QUAIL. An air-launched diversionary missile developed by the McDonnell Aircraft Corporation.

GREENWICH APPARENT TIME. Apparent time measured with reference to the Greenwich meridian.

GREENWICH HOUR ANGLE. The angular distance measured in the plane of the equator from the point of intersection of the Greenwich meridian to the point of intersection of the hour circle (see **equatorial coordinates**) through a celestial body (or other object) in the direction of apparent rotation (west) of the **celestial sphere**.

GREENWICH MERIDIAN. The meridian on which the Royal Observatory at Greenwich, England, is located; the zero meridian from which longitude is measured. (See **prime meridian**.)

GRID. (1) The pattern of intersecting lines set up in accordance with a grid system, and superimposed upon charts, aerial photographs, or the like, to permit ready location of points on the ground. (2) A grid line. (3)

A part in the rear section of a rocket motor, which supports the powder grain, but allows enough clearance for the propellant gases to escape to the nozzle. (4) An electrode in a vacuum tube for controlling the flow of electrons.

GRID BIAS. In electrical work, a voltage whose principal function is to locate the operating point on the characteristic of a piece of apparatus. The term is most commonly applied to the grid voltage of a vacuum tube, in which case it means the d-c voltage (other than signal voltage) applied between the cathode and control grid of the tube. In this connection the term C-bias is also commonly used. The bias may be obtained from a source of d-c voltage, from the potential drop across a resistor (cathode resistor) in the cathode circuit or, when the grid carries current, from the drop across a resistor in the grid circuit. The first method is called fixed bias and the latter two self-bias.

GRID, CONTROL. A grid, ordinarily placed between the cathode and an anode, for use as a control electrode.

GRID LEAK. The resistance in the grid circuit of a vacuum tube. (See tube, vacuum.) By "leaking" an insignificant current it is enabled to produce a bias voltage.

GRID LINE. Any one of the intersecting lines shown as coordinates on a grid.

GRID QUADRANGLE. The quadrangle, usually shaped like a rectangle or trapezoid, formed by the intersection of four grid lines.

GRIVATION. The variation between grid north and magnetic north, usually expressed as an angle.

GROUND. (1) The earth's surface, often restricted to the land surfaces. (2) The earth, or a substance serving for it, used to complete an electrical circuit. (3) A metallic connection used to ground a circuit.

GROUND ANTENNA DATA LINK SYSTEM. Electronic equipment that provides a radio-frequency link between test equipment and equipment under test.

GROUND CLUTTER. Unwanted radar echoes from terrain in the vicinity of a target which tend to obscure it.

GROUND-CONTROLLED APPROACH. A method of landing aircraft in poor visibility by directing the operation with the aid of a ground radar station.

GROUND EQUALIZER INDUCTORS. Coils of relatively low inductance, placed in the circuit connected to one or more of the grounding points of an antenna to distribute the current to the various points in any desired manner.

GROUND-PLANE ANTENNA. Antenna, counterpoise.

GROUND-REFLECTED WAVE. Wave, ground-reflected.

GROUND RETURN. Clutter, radar.

GROUND (SEA) CLUTTER. Unwanted radar echoes from terrain (or sea) in the vicinity of a target.

GROUND SHOCK. The magnitude, direction, and duration of the shock at a given point on the surface or below the surface of the earth resulting from a nuclear explosion of a given magnitude and burst position.

GROUND SPEED. The horizontal component of the velocity of an aircraft or missile relative to the earth's surface beneath it. It is the same as true air speed only if the air is stationary with respect to the earth's surface.

GROUND START SYSTEM. A technique of power plant ignition and burning in which working propellants are supplied from a ground source prior to launch in order to conserve tank supplies for actual flight. As soon as proper burning from the ground supplies is achieved, the missile powerplant is switched to on-board tankage and is allowed to lift off.

GROUND SUPPORT EQUIPMENT (GSE). All ground equipment that is part of the complete weapon system and that must be furnished to insure its support. Included are all implements or devices required to inspect, test, adjust, calibrate, appraise, gage, measure, repair, overhaul, assemble, disassemble, transport, safeguard, record, store, actuate, service, launch, and otherwise support and maintain the functional operating status of a weapon system, sub-system, end item, or component. *Test GSE* is ground support equipment used

to support the missile development program. *Operational GSE* is ground support equipment used in the operational weapon system.

GROUND SYSTEM OF ANTENNA. Antenna, ground system of.

GROUND-TO-AIR MISSILE. Missile, ground-to-air; missile, guided; model designation.

GROUND-TO-GROUND MISSILE. Missile, ground-to-ground; missile, guided; model designation.

GROUND WAVE. (1) In general, a surface wave (see *wave, surface*). (2) The energy which reaches the radio receiving antenna from the transmitter by travel along the surface of the earth rather than by reflection from the ionosphere. The ground wave is unaffected by seasonal or diurnal variations and is consequently very reliable for communication. However, it is attenuated by absorption of the earth and gradually becomes too weak to furnish a reliable signal. This attenuation depends in a complicated way upon the frequency, the soil conductivity and dielectric constant, but increases markedly with frequency. Thus, while it is suitable for communication over several thousand miles at the lower radio frequencies (over a hundred or two in the broadcast band) it becomes almost useless at the high frequencies. See *fading* for its effect on the total received signal.

GROUND ZERO (G.Z.). That point on the earth's surface directly below, at, or above where a nuclear warhead is detonated.

GROUP. In telemetering, a number of associated subcarrier oscillators.

GROUP VELOCITY. (1) The velocity of propagation of the crest of a group of interfering waves where the component wave trains have slightly different individual frequencies and phase velocities. In a dispersive medium in which the phase velocity V is a function of the frequency f , the group velocity U has the form

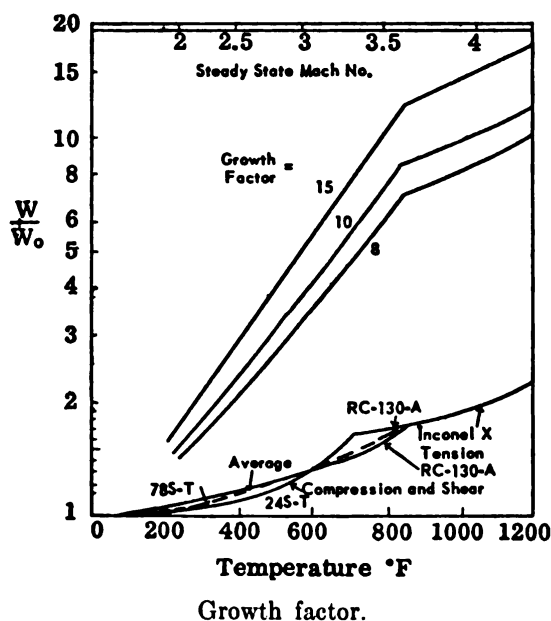
$$U = \frac{V_0}{1 - \frac{f_0}{V_0} \left(\frac{dV}{df} \right)_0}$$

where V_0 is the mean phase velocity of the component wave trains, f_0 the average fre-

quency in the group and $\left(\frac{dV}{df} \right)_0$ is the value of the derivative taken at the average frequency.

(2) The Institute of Radio Engineers definition of group velocity is as follows: Of a traveling plane wave, the velocity of propagation of the envelope of a wave occupying a frequency band over which the envelope delay is approximately constant. It is equal to the reciprocal of the rate of change of phase constant with angular frequency. Group velocity differs from phase velocity in a medium in which the phase velocity varies with frequency.

GROWTH FACTOR. A factor defining the increase in weight, volume, power, or any other parameter caused by the increase in the quantity of a component in a system, or by the addition of a new element; e.g., an increase in a missile payload causes an increase in gross weight, etc. The ratio of the latter to the former is the growth factor. (See Figure.)



GSE. Ground support equipment.

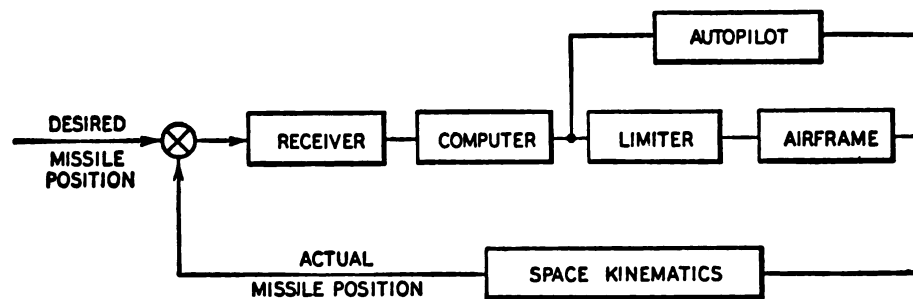
G-SUIT. A suit that exerts pressure on the abdomen and lower parts of the body to prevent or retard the collection of blood below the chest under positive acceleration. (Cf. *pressure suit*.)

GUARD BAND. In electronic propagation, a narrow band of unassigned frequencies located

between assigned frequency channels used to prevent cross talk.

GUIDANCE. The processes of intelligence gathering and maneuvering required by a missile, probe or space ship to reach a specified

direct a missile. The beam, which may be either fixed in elevation and azimuth or moving, may be a radar beam, a light beam, or a beam of some other type. Equipment is built into the missile, such that the missile can determine when it is in the center of the beam,



Simplified block diagram of generalized guidance system.

destination, with special connotation on the flight path and on the information for determining the proper course whether computed externally or within the missile itself. Missile guidance may be divided into two phases: attitude control and path control. It may also be separated into three phases of the flight path: initial, midcourse, and terminal. Whatever the guidance scheme, its basic pro-

or can determine the direction and magnitude of the error when it has deviated therefrom. Also built into the missile are suitable electronic circuits, servo motors, aerodynamic surfaces, and/or other equipment, such that the missile by its own initiative, will return toward the center of the beam when it has deviated therefrom for any reason. (See figure above.)

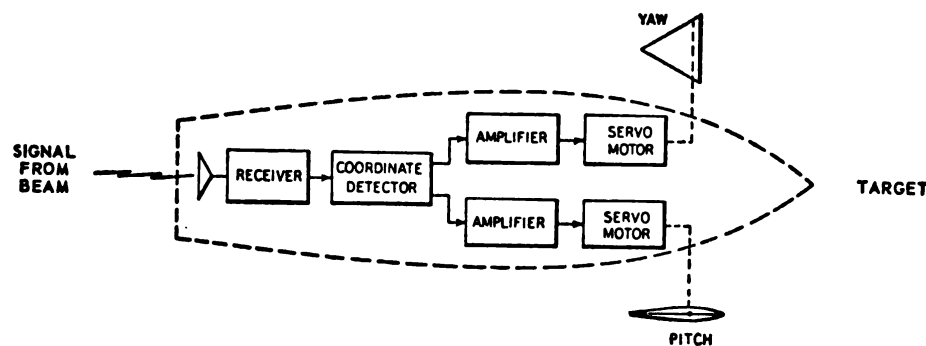


Fig. 1. Beam rider guided missile.

cedure is to compare the actual flight path with the desired path, and to correct for deviations by an error detecting device in the intelligence system which actuates the necessary controls. These controls have as their primary function the conversion of guidance commands into course correction responses. (See Fig. 1 and Fig. 2.)

GUIDANCE, BEAM RIDER. A system for guiding missiles which utilizes a beam directed into space, such that the center of the beam axis forms a line along which it is desired to

GUIDANCE, CELESTIAL. Navigation, celestial.

GUIDANCE, CELESTIAL-INERTIAL. A system in which the basic inertial guidance is corrected by supplementary position and/or velocity information as obtained from celestial observations: e.g., optical or radio star trackers.

GUIDANCE, COMMAND. A guidance system wherein intelligence transmitted to the missile from an outside source causes the mis-

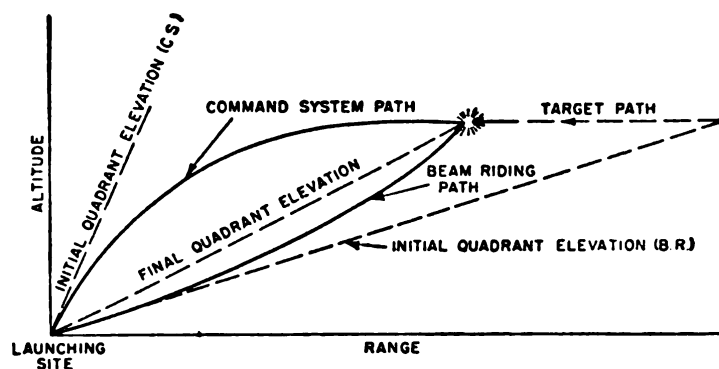


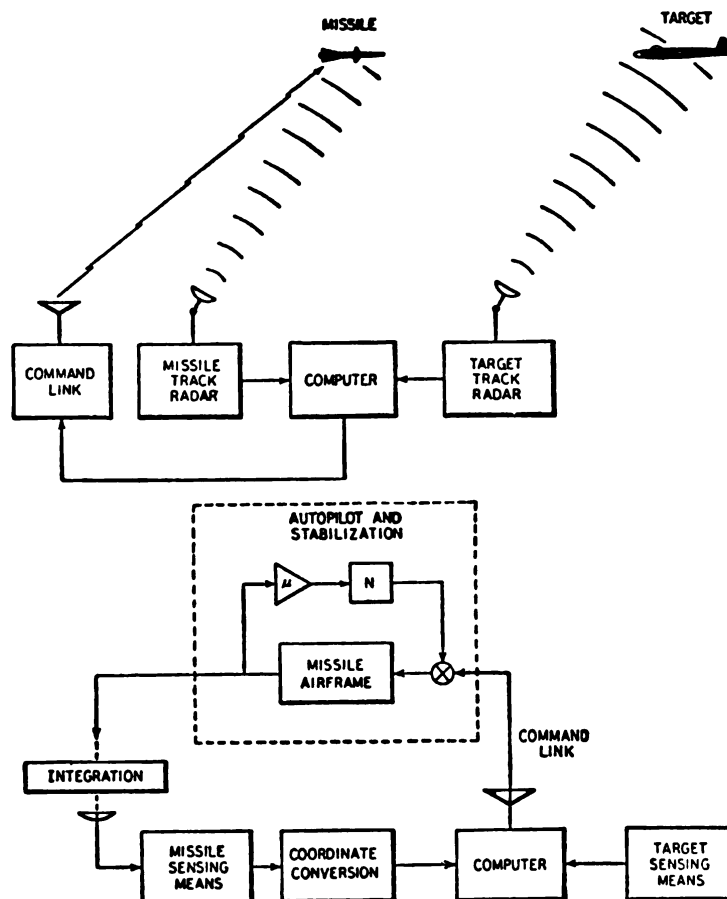
Fig. 2. Command and beam rider flight paths

sile to traverse a directed path in space. (See figure below.)

GUIDANCE, HOMING. A guidance system by which a missile steers itself towards a target by means of a self-contained mechanism which is activated by some distinguishing characteristic of the target. (See Fig. 1. Page 294.)

GUIDANCE, HOMING, ACTIVE. A system of homing guidance wherein both the source for illuminating the target and the receiver are carried within the missile. (See Fig. 2, Page 294.)

GUIDANCE, HOMING, PASSIVE. A system of homing guidance wherein the receiver



Generalized command guidance system.

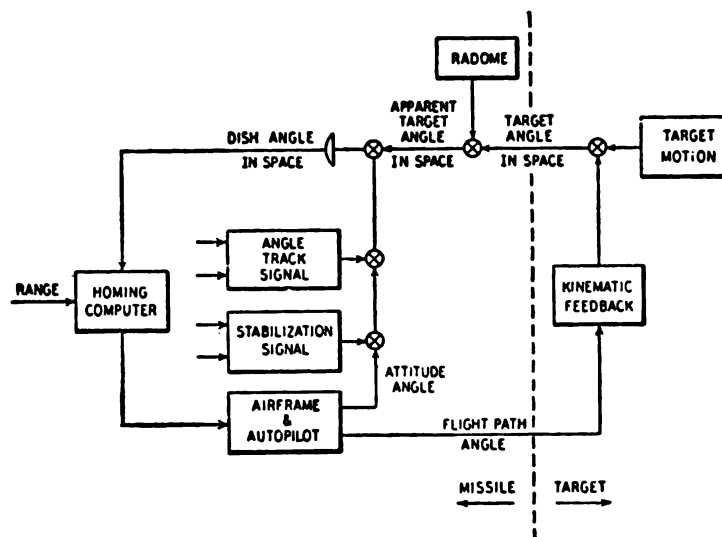


Fig. 1. General homing guidance system.

in the missile utilizes natural radiations from the target. (See Fig. 3, below.)

GUIDANCE, HOMING, SEMIACTIVE. A system of homing guidance wherein the receiver in the missile utilizes radiations from a target which has been illuminated from a source other than the missile. (See Fig. 1, Page 295.)

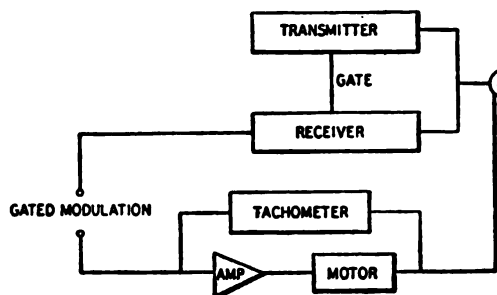


Fig. 2. Tracking loop of an active homing system.

GUIDANCE, HYPERBOLIC. The guidance or control of a **guided missile** in which the difference in the time delay of radio signals transmitted simultaneously from two ground stations, arriving at the missile at different time intervals, controls the position of the missile.

GUIDANCE, INERTIAL. A system independent of information obtained from outside the missile, the sensitive elements of which system make use of the principle of Newton's second law of motion. (See Fig. 2, Page 295.)

GUIDANCE, MIDCOURSE. The guidance applied to a missile between the termination of the launching phase and the start of the terminal phase of guidance.

GUIDANCE PATHS. Regardless of the guidance system selected, some decision as to what path the missile will fly is required. Assuming a missile required to hit a moving target (such as an antiaircraft missile) various guidance paths are possible; such as beam

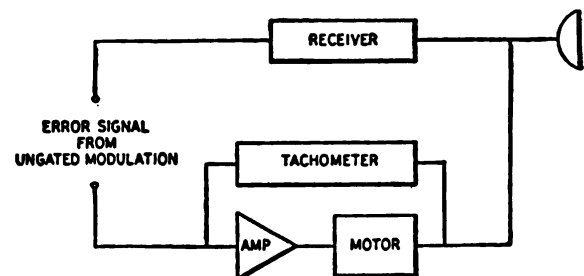


Fig. 3. Tracking loop of a positive homing system.

rider, pursuit, proportional navigation, collision and fixed-lead.

GUIDANCE, PRESET. A technique of missile guidance wherein a predetermined path is set into the guidance and control mechanism of the vehicle and cannot be adjusted after launching. A missile using preset guidance is not a true guided missile.

GUIDANCE SYSTEM. One of the systems in a **ballistic missile** that puts the missile on

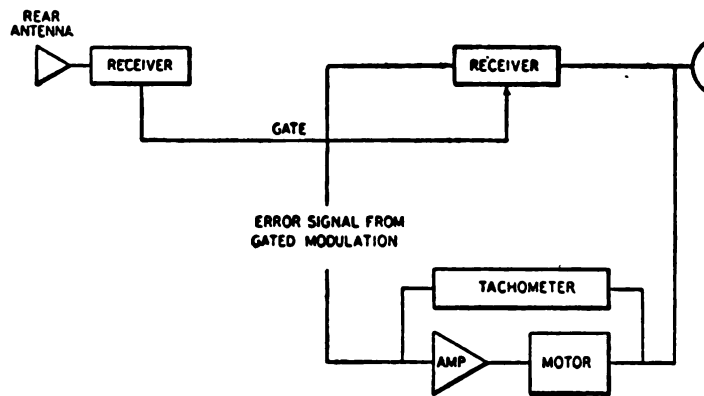


Fig. 1. Tracking loop of a semiactive homing system.

a desired trajectory at a desired velocity prior to thrust cutoff, or a system in a **guided missile** that establishes the desired path from launch to target.

GUIDANCE SYSTEM EVALUATION. In evaluating a guidance system qualitatively, the following factors are to be considered: range, accuracy, reliability (i.e., after long storage, rough handling, etc.), complexity, cost, invulnerability to guidance and tactical countermeasures, and commercial availability.

GUIDANCE TAPES. Magnetic or paper tapes that are placed in a missile or its computer, and on which there previously has been entered information needed to program desired events in the missile during flight.

GUIDANCE, TERMINAL. The guidance applied to a missile between the termination of the midcourse guidance and impact with or detonation in close proximity to the target.

GUIDANCE, TERRESTRIAL REFERENCE. A technique of missile control wherein the predetermined path set into the control system of a missile can be followed by a device in the

missile which reacts to some property of the earth, such as magnetic or gravitational fields.

GUIDANCE, TRACK-COMMAND. A method of missile guidance wherein both target and missile are tracked by separate radars and corrective commands are sent to the missile. (See **guidance command**, and its illustration.)

GUIDED. Controlled or controllable as to direction by preset mechanisms, radio commands, or built-in-self-reacting devices.

GUIDED AIRCRAFT MISSILE. A guided missile launched, or designed for launching, from an aircraft.

GUIDED AIRCRAFT ROCKET. An air-launched rocket powered missile. Normally these rockets are used against other aircraft, but can also be used against ground targets. The guided aircraft rocket (*GAR*) is a specific type of guided aircraft rocket, i.e., it is an aircraft missile having a rocket power plant.

GUIDED BALLISTIC MISSILE. Missile, guided ballistic.

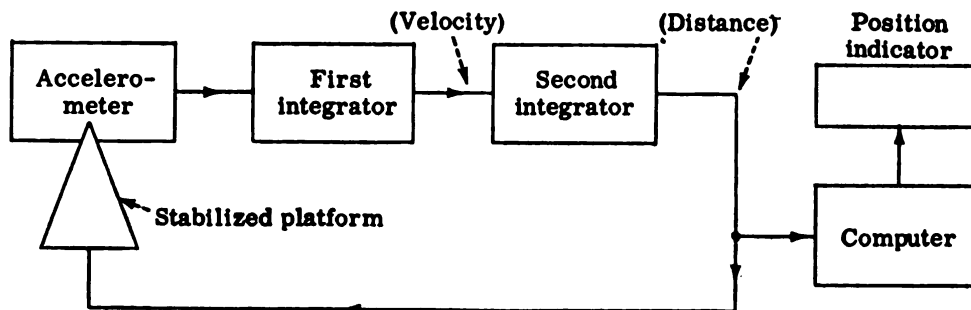


Fig. 2. Schematic of inertial guidance system.

GUIDED MISSILE. (1) Broadly, any missile that is subject to, or capable of, some degree of guidance or direction after having been launched, fired, or otherwise set in motion. (2) Specifically, an unmanned, self-propelled flying vehicle (such as a pilotless aircraft or rocket) carrying a destructive load and capable of being directed or of directing itself after launching or take-off, responding either to external direction or to direction originating from devices within the missile itself. (3) Loosely, by extension, any dirigible projectile. (See **ballistic missile**, **self-guided missile**.)

GUIDED MISSILE CONTROL. The guidance or direction exercised over a guided missile during its flight to a target.

GUIDED MISSILE SYSTEM. Missile system, guided.

GUSSET. A small brace (usually triangular in shape) fastened in a corner or junction between two parts. It has the purpose of strengthening the joint. A gusset is usually glued, welded or riveted in place following assembly of the two parts to which it is attached. (See **fairing** and **fillet**.)

GUTTER. In an air-breathing engine, the portion of a flame holder which is grooved to improve stability of the flame holding operation.

G-WEIGHT. A weight, free to move axially in a missile frame and used to measure accelerations. (See **accelerometer**.)

GYRATOR CIRCUIT. A circuit element which is so named because it violates the **reciprocity theorem** as does the **gyroscope**.

GYROCOMPASS. (1) Any compass which depends for its action on the conservation of the angular momentum of a spinning body. (See **gyroscope**.) In the usual gyrocompass, a motor-driven wheel is mounted on an axis in gimbals. The combined use of friction and of a gravitational restoring torque insure that the equilibrium position of the axis of rotation is along the north-south horizontal line, so the gyrocompass indicates true north regardless of the orientation in which it is started. (2) A **directional gyroscope**.

GYRO DRIFT. Gyroscope drift.

GYRO FLUX-GATE COMPASS. A compass in which a triangular flux gate, horizontally stabilized by a **gyroscope**, senses the horizontal component of the earth's magnetic field, and, being fixed with respect to the vehicle, reacts to each change in heading by a change in current, the current being converted through an amplifier into mechanical motion on the dial of a master indicator.

GYRO TRANSFER TABLE (GTTS). A portable precision gyro instrument designed to transfer physically the direction of vertical and the true north from a reference instrument (normally a Ship's Inertial Navigation System) to another part of the Ship's Navigation or Fire Control Systems or to a missile.

GYROPILOT. A form of rudimentary dead-reckoning guidance which automatically controls a missile in **attitude** and **flight path**. Essentially, the gyropilot consists of gyroscopes used as references for horizon and direction, a suitable error-sensing system, and a power amplifying **servo-control** network for changing the error signals into fin movements, or for activating other controls to correct the errors.

GYROSCOPE. A heavy wheel or disc arranged to be set into rapid rotation, and to maintain a fixed axis of rotation, usually by a gimbal-mounting whereby it is free to turn in one or more directions without undergoing a change in the direction of the axis of rotation. Gyroscopes are used in aircraft instruments for indicating **artificial horizons**, in bomb sights, and in **autopilots**. In larger models they are used in **gyrocompasses**, or for the stabilization of ships and heavy guns. In missiles, gyros are used in a variety of ways, depending on their orientation in space with respect to the missile, and depending also on the way that the gyroscope is restrained in its mountings. The technique of the use of a gyroscope as a force-sensing instrument is to mount it under restraint allowing one degree of freedom (the sensitive axis), and to measure the amount of the incident force on this axis by noting the tendency to precess on a perpendicular axis. A simple arrangement of this type is shown in Figure 1. With the gyro mounted in the missile in the orientation shown, any rolling of the missile exerts a torque which is felt by the gyro as a precession and evidenced by pull against the

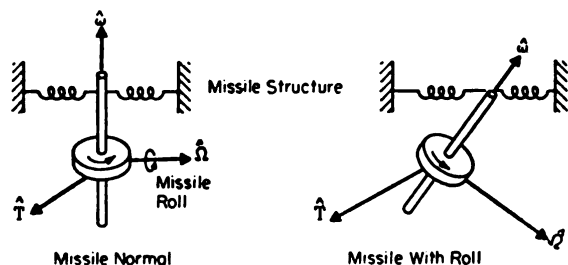


Fig. 1. Gyro precession used as an altitude sensor.

spring restrainers shown. A measurement of roll could be made from the amount of tension produced in one of the springs.

The methods of vector analysis are useful in the analysis of gyroscope action. The most general usage for the direction of rotational vectors is the right hand rule: the fingers of the right hand curl in the direction of rotation if the thumb points in the same direction as the head of the arrow of the vector). Gyro forces or accelerations are commonly expressed in terms of three vectors. These are: spin, precession and torque, and they follow a conventional arrangement described by a second right hand rule, in which the thumb, index finger and middle finger are pointed in three mutually perpendicular directions. By proper choice of directions, the thumb represents the precession vector, the forefinger represents the spin vector, and the second finger represents the torque vector. (See Figure 2.)

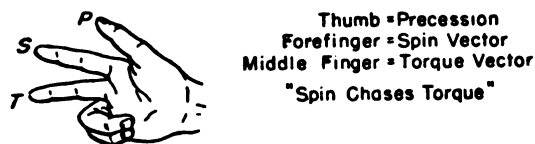


Fig. 2. Right hand rule for gyroscope.

A gyro has an angular momentum due to rotation, which is also a vector quantity. It is denoted by:

$$\mathbf{M} = I\omega$$

where \mathbf{M} is the angular momentum due to rotation, I is the moment of inertia and ω is the spin. ($I = \frac{mk^2}{g}$, where m is the mass of the rotating element, g is the acceleration of gravity, and k is the radius of gyration). Similarly, a gyro also has a precession momentum given by:

$$\mathbf{N} = J\Omega$$

where \mathbf{N} is the precession momentum, J is

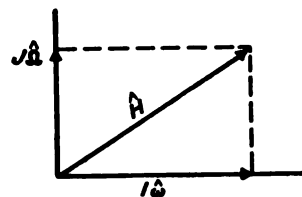


Fig. 3. Total angular momentum of gyroscope.

moment of inertia of the gyro about the precession axis, and Ω is the precession. The vector sum of \mathbf{M} and \mathbf{N} is the total angular momentum, \mathbf{H} . That is,

$$\mathbf{H} = \mathbf{M} + \mathbf{N} = I\omega + J\Omega$$

The time rate of change of the vector \mathbf{H} , ($d\mathbf{H}/dt$), is defined as the torque. Thus,

$$d\mathbf{H}/dt = \Omega \times \mathbf{H}$$

$$\Omega \times \mathbf{H} = \Omega \times I\omega + \Omega \times J\Omega$$

$$\Omega \times \mathbf{H} = d\mathbf{H}/dt = \Omega \times I\omega \quad (\text{since } \Omega \times J \rightarrow 0)$$

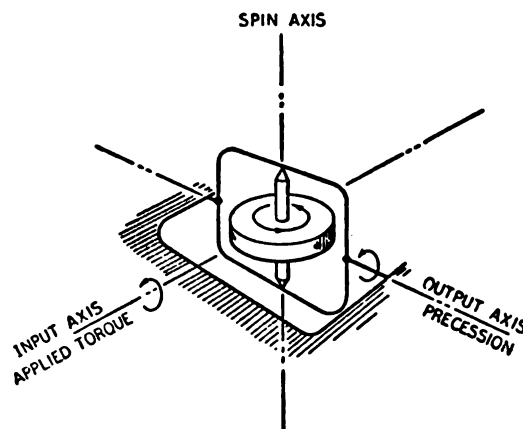
$$\mathbf{T} = \Omega \times I\omega$$

GYROSCOPE, BODY MOUNTED. Body mounted gyroscope.

GYROSCOPE, CRYOGENIC. A gyroscope actuated by changes in the plane of spin of electrons at near absolute zero instead of the conventional spinning flywheel. (Development Stage.)

GYROSCOPE, DIRECTIONAL. A gyroscopic instrument for indicating direction. It contains a free gyroscope which holds its position in azimuth, and thus indicates angular deviation from the course.

GYROSCOPE, DISPLACEMENT (FREE ATTITUDE). A sensing instrument for



Free gyro, showing gyroscopic precession.

establishing a space-reference for a missile which makes use of a gyroscope's inherent characteristic of attempting to maintain its spin axis fixed in space. The gyroscope is mounted on gimbals which give it two-degrees of freedom. (See Fig. 1, below.)

GYROSCOPE DRIFT. The difference between the actual and theoretical line of direction of a gyroscope due to three general sources: (a) Unbalance—due to unsymmetry of manufactured parts, temperature, etc. (b) Bearing Friction—due to gimbal friction. Spin axis friction does not cause precession if the friction is symmetrical. (c) Gimbal inertia.

GYROSCOPE, FOUCAULT. A gyroscope wheel which is supported by gimbals such that it is allowed to turn freely about any axis, and the parts are balanced to prevent gravity from exerting a torque on the wheel.

GYROSCOPE, FREE. A gyroscope mounted in two or more gimbal rings so that its spin axis is free to maintain a fixed orientation in space.

GYROSCOPE, INTEGRATING. An adaptation of the familiar rate gyroscope; both have only a single degree of freedom. The restraining force exerted by the viscous damping is proportional to the gyroscope precession rate instead of the displacement. (See **HIG (GYRO)**.)

GYROSCOPE, INTEGRATING (PENDULOUS) ACCELEROMETER. A gyroscope

capable of sensing and integrating a linear acceleration to obtain the resultant velocity. It is unsymmetrically suspended so that acceleration produces a precession force resulting in an angular displacement of the gyroscope axis proportional to the time integral of the acceleration. (See Fig. 2.)

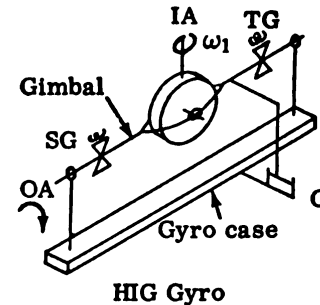


Fig. 2. Schematic of integrating gyroscope.

GYROSCOPE PRECESSION. The force-motion relationship of a spinning gyroscope resulting from the application of Newton's second law of motion whereby the time rate of change of angular momentum of a body about any given axis is equal to the torque applied about the given axis.

$$T = I\omega\Omega$$

where T is the torque, I is the inertia of the gyro rotor about the spin axis, ω , is the rotor speed, and Ω is the angular velocity about the output axis. Precession is always in such a direction as to align the direction of rotation of the rotor with the direction of rotation of the applied torque. (See **gyroscope**.)

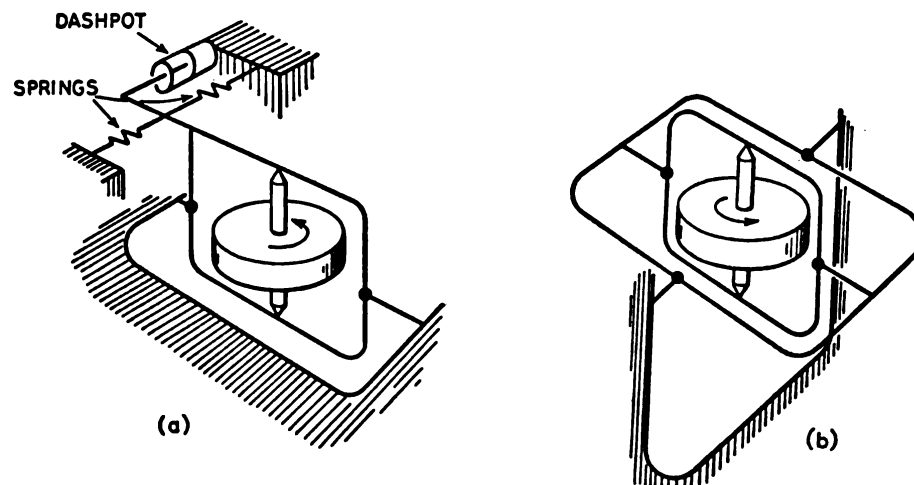


Fig. 1. Gyroscope gimbal systems.

GYROSCOPE, RATE. A gyroscope with a single gimbal mounting, such that rotation about an axis perpendicular to the axis of the gimbal and to the axis of the gyroscope produces a precessional torque proportional to the rate of rotation. This is a single-degree-of-freedom gyroscope, mounted as shown in Fig. a., while Fig. b shows the mounting of a two-degree-of-freedom gyroscope.

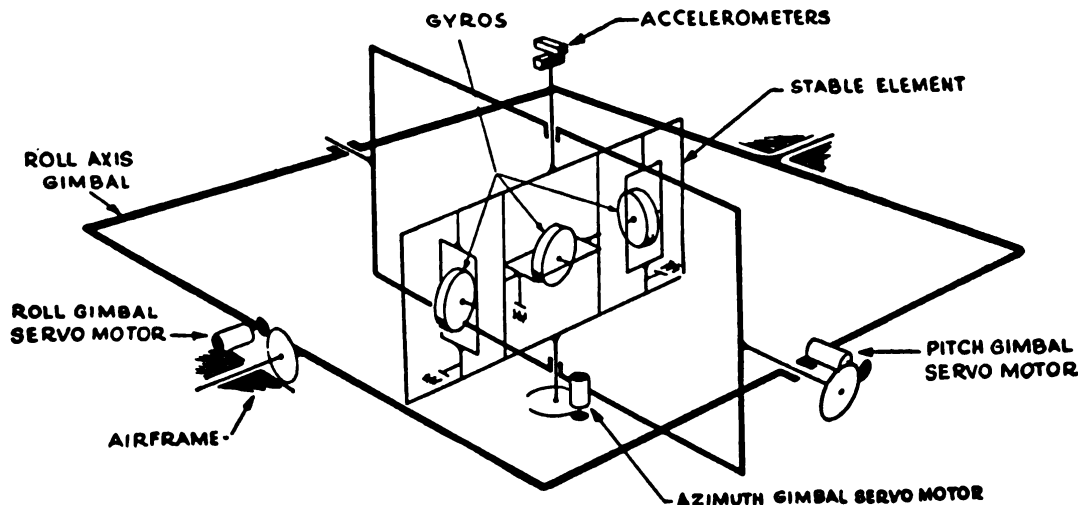
GYROSCOPE, SINGLE DEGREE OF FREEDOM. A gyroscope with rotational axes, but a single gimbal axis. The geometric position at any instant is expressed by a number. If the restraint of the gimbal is a spring, the unit is classed as a rate gyroscope. If the restraint is viscous, the unit is classed as an integrating or displacement gyroscope. (See corresponding entries.)

GYROSCOPE-STABILIZED PLATFORM. In inertial guidance, a gyroscopically stabilized platform for mounting accelerometers to maintain them fixed either in a space or earth reference system despite changes in missile position and attitude. (See Figure here, also Figure facing Page 219.)

programming the position of the reference axes. Torquers may be operated on a-c or d-c.

GYROSCOPE, UNBALANCED. A gyroscope which is unbalanced to make it sensitive to acceleration. Any acceleration about the sensitive axis produces gyroscope precession (displacement) at a rate proportional to acceleration. This makes the total angle of gyroscope displacement proportional to the integral of acceleration, hence proportional to vehicle velocity. (See *gyroscope, integrating (pendulous)*.)

GYROSCOPE, VERTICAL. The vertical gyroscope is a gyroscope which is positioned by a gravity-sensitive element such as a pendulum or bubble level. There have been many ingenious arrangements developed to erect, and to maintain erect, vertical gyroscopes. In principle, all of the arrangements employ a means of measuring the direction and the vertical gravity and, in the event of an error between this direction and the vertical as indicated by the gyroscope, of applying a torque to the rotor to precess it in the



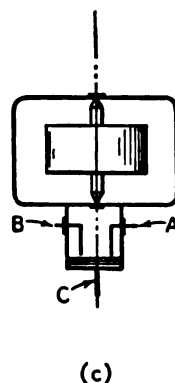
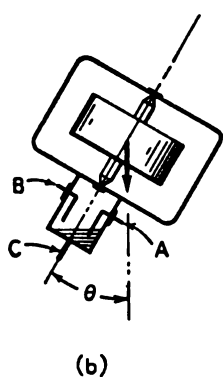
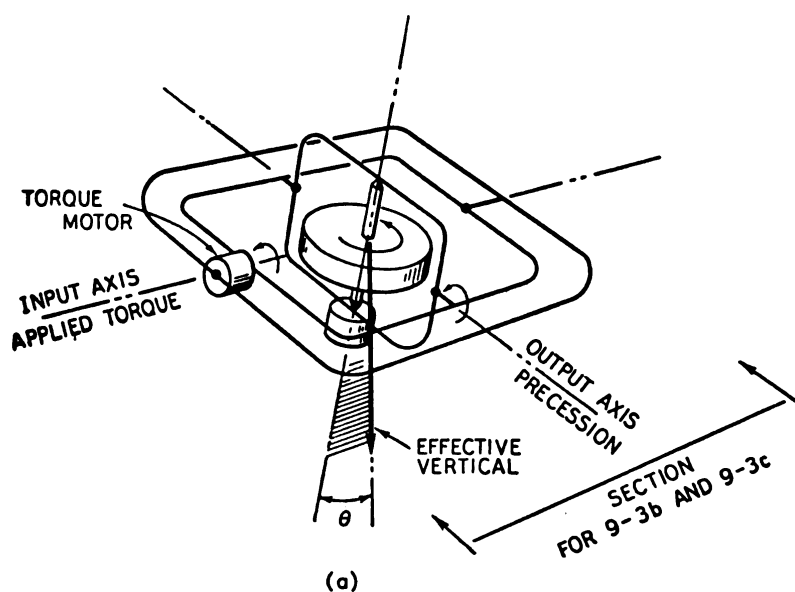
Schematic of a gyroscope stabilized platform on which are mounted linear accelerometers.

GYROSCOPE TORQUE HYSTERESIS. The residual torque in a d-c torquer (see *gyroscope, torqueing*) resulting from the magnetic memory of the torque generator when the excitation is removed.

GYROSCOPE TORQUEING. The process of applying an external signal to the gimbals of a displacement gyroscope as a means of

direction to correct the error. Owing to the nature of gyroscopic precession, the axis about which the torque is applied is at right angles to the direction of precession required to correct the measured error. (See figure on Page 300.)

GYROSCOPIC HORIZON. A gyroscopic instrument that indicates the lateral and longitudinal attitude of a vehicle by simulating



Principles of vertical gyroscope operation.

the natural horizon. This gyroscope has a single degree of freedom.

GYROSYN. A trade name for a compass that consists of a directional **gyroscope** synchronized with the horizontal component of the earth's magnetic field by means of a **flux gate**.

GYROTRON. An electromechanical device using the phase comparison of the amplified output from pick-ups of a mechanical vibrating element (tuning-fork oscillator) to indicate motion of the system. Use is made of the phase distortion of the tuning fork vibration which occurs due to a torque differential exerted on the fork tines by a rotation imparted by a motion of the mount to which the gyro-

tron is mounted. The gyrotion vibrates at constant frequency, normally around 2000 cycles per second. This vibration causes an increase in angular momentum as the tines swing outward, at the vibration frequency. The change in angular momentum develops a torque about the axis of symmetry of the tuning fork. This change in momentum alters the vibrating frequency of the fork proportionally. The altered frequency is compared to a reference signal undistorted by movement of the mount, but in phase with the signals originally developed from the tines. A phase detector applied to measure this difference in phase can detect angular velocities as small as one degree per hour.

G.Z. Ground Zero.

H

H. (1) Planck constant (h). (2) Dirac h (\hbar). (3) The gauss (H). (4) Magnetic intensity, magnetic force, or magnetizing force (**H**). (5) The henry or Henry law constant (H). (6) Height, depth or thickness (h). (7) Hour (h). (8) Heat flow per unit time per unit area (h). (9) Hamiltonian operator. (H). (10) Enthalpy, total (H), per atom or molecule (h or h_m), per mole (h , H or h_m), per unit mass (h). (11) Boltzmann function (H). (12) Humidity (H). (13) Degree of electrolysis or hydrolysis (h). (14) Miller index (h , k , l). (15) Hydrogen (H). (16) Radius of lens zone (h). (17) Altitude (h). (18) Hydrodynamic head (h).

H AND D CURVE (HURTER AND DRIFIELD CURVE). A characteristic curve of a photographic emulsion which is a plot of **density** against the logarithm of **exposure**. It is used for the control of photographic processing, and for defining the response characteristics to light of photographic emulsions. (See **gamma**.)

H WAVE. A transverse electric wave. (See **wave, transverse, electric**.)

HADC. Holloman Air Development Center; Alamogordo, New Mexico.

HAFNIUM. Metallic element. Symbol Hf. Atomic Number 72.

HAIL. Pellets of ice ranging from about $\frac{1}{16}$ inches in diameter to as much as 4 or 5 inches. Hailstones are often transparent, but more frequently are translucent, being formed of alternate layers of clear and opaque ice. Hail usually falls from thunderstorms.

HALATION. The halo which is sometimes observed in photographic images of bright objects, or sources of light, is known as halation when due to light reflected back into the emulsion from the rear of the support. Ordinarily, the halo produced by halation is indistinguishable from that due to the spread-

ing of light within the emulsion which is known as irradiation. The size and density of the halo, when due to halation, increase with the exposure and the degree of development and decrease with an increase in the turbidity and thickness of the emulsion.

Halation can be almost entirely prevented by placing a light-absorbing layer either on the back of the support or between the emulsion and the support. Light-absorbing layers of this type are termed *backings*. Dyes which are decolorized by the sulfite in the developer have replaced the old mixtures of lamp black and similar materials which had to be removed by washing in water and discolored the developer so that it could no longer be used.

HALF-ADDER. A circuit having two input and two output channels for binary signals (0, 1) and in which the output signals are related to the input signals according to the following:

Input to		Output from	
A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

where A and B are the two input channels and S and C are the two output channels representing Sum and Carry respectively.

HALF-LIFE. For a given substance, the time required for one-half of it to undergo a process. In particular, the time required for disintegration of one-half the atoms of a sample of a radioactive substance. Its relation to the **disintegration constant** and the **mean life** is as follows:

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda} = 0.693\tau$$

where $t_{1/2}$ is the half-life, λ is the disintegration constant and τ is the mean life.

HALF POWER (POINT). In an antenna pattern, the power on each side of the main lobe which is 3 decibels less than the maximum value.

HALF-SILVERED MIRROR. A translucent mirror coated with a metallic film of such thickness that it transmits approximately half of the light falling on it at normal incidence, and reflects approximately the remainder of the light.

HALF-WAVE ANTENNA. An antenna whose length is one half the radiated wavelength. The distance between the **half-power points** is a measure of the directivity or beam width of the antenna system.

HALF-WAVE RECTIFIER. Rectifier, half-wave.

HALOGEN. The family of elements consisting of **fluorine, chlorine, bromine, iodine** and **astatine**. They are similar in chemical properties, due to a similarity in (outer) electronic configuration of their atomic structure.

HANGFIRE. The delayed ignition of a rocket propellant or igniter.

HAPO. Hanford Atomic Products Operation; operated by General Electric for the Atomic Energy Commission; Hanford, Washington.

HARD POINTS. Structurally reinforced areas on a missile's exterior surface which are suitable for supporting it during handling and stowage.

HARD STRUCTURE. A structure, e.g., for missile launching, designed to withstand nuclear weapon effects of a stated magnitude.

HARD TARGET. A U.S. Air Force term for an underground or otherwise revetted or protected target. It is distinguished from a soft target or exposed (i.e., above ground), target.

HARD TUBE. A vacuum tube that has been evacuated to a high degree.

HARDNESS. (1) A target's relative invulnerability to damage, particularly from a nuclear explosion. (2) The property of an installation, facility, or equipment that will prevent an unacceptable level of damage resulting from aerial bombardment. (3) The

property of firmness or resistance possessed by solids and very viscous liquids. The degree of hardness of a substance is shown by its resistance to cutting, scratching, or abrasion. (4) The presence in water of certain salts which form insoluble deposits in boilers, which form precipitates with soap, and which have other objectionable effects.

HARDNESS, BIERBAUM. The relative hardness of a micro-constituent of an alloy, determined by an instrument called the Bierbaum microcharacter. The method involves the measurement of the width of a scratch produced by a standard diamond point, under a standard pressure.

HARDNESS, BRINNELL. A measure of the relative hardness of the surface of a substance, obtained by measuring the depth of indentation of a standard steel ball at a standard pressure; and then computing the hardness by an expression whereby the value obtained is directly proportional to the applied pressure, and inversely proportional to the depth of penetration.

HARDNESS, ROCKWELL. A measure of relative hardness of the surface of a substance, based on the indentation made by a $\frac{1}{16}$ ", $\frac{1}{8}$ " or $\frac{1}{4}$ " standard steel ball, or a conical diamond with an apex angle of 120°. The results are reported by using numbers to denote the load in kilograms, and letters to denote the ball or diamond producing a given indentation.

HARDNESS SCALE, MOH. A system in which all solid substances are classified in order of increasing hardness, so that the hardness of any particular substance may be expressed by a number. The numbers were established by assigning the integers from one to ten to arbitrarily chosen substances of increasing hardness, ranging from talc which was given the number one, to diamond which was given the number ten. This was the original Moh scale and is still generally used. In the new Moh scale, fifteen substances are used, and diamond has the number fifteen. The hardness of any substances not on the scale is determined by the scratch test, i.e., by comparing its hardness with that of the various substances in the standard scale, utilizing the principle that the harder of the two substances will scratch the softer one, and will

not be scratched by it. When a substance is found to have hardness between two of the standard substances in the scale, this fact is expressed by use of decimal notation. Thus, the mineral having hardness of 6.65 would be harder than feldspar 6, and softer than quartz 7.

The original Moh's scale assigned the integral numbers as follows: 1—Talc; 2—Gypsum; 3—Calcite; 4—Fluorite; 5—Apatite; 6—Orthoclase; 7—Quartz; 8—Topaz; 9—Corundum; 10—Diamond. In the new Moh's scale the numbers above five have been re-assigned as follows: 6—Orthoclase, Periclase; 7—Vitreous Pure Silica; 8—Quartz, Stellite; 9—Topaz; 10—Garnet; 11—Tantalum Carbide, Fused Zirconia; 12—Tungsten Carbide, Fused Alumina; 13—Silicon Carbide; 14—Boron Carbide; 15—Diamond.

HARDNESS SCALE, SHORE. A scale of relative hardness based on the elastic rebound of a heavy plummet, with a standard hard point, which is dropped on the surface of the specimen from a fixed height.

HARDWARE. Colloquial term for finished pieces of equipment or component parts that constitute an operating machine or device, such as a missile or vehicle.

HARDWARE, BODY. Body hardware.

HARMONIC. (1) A sinusoidal quantity having a frequency which is an integral multiple of the fundamental frequency of a periodic quantity to which it is related. For example, a wave, the frequency of which is twice the fundamental frequency, is called the second harmonic. (2) In musical terms, a harmonic is a partial whose frequency is an integral multiple of the fundamental frequency. (See **frequency, fundamental**.)

HARMONIC DISTORTION. Distortion, harmonic.

HARTLEY. In communication theory, a unit of information which is generally defined as being equal to 3.219 bits.

HARTLEY OSCILLATOR. An oscillator in which the parallel-tuned tank circuit is connected between grid and plate, the inductive element of the tank having an intermediate tap at cathode potential, with the necessary feedback voltage obtained across the grid-

cathode portion of the inductor. The inductive feedback is used to generate the basic oscillation.

HASH. Electrical noise produced by a mechanical vibrator or by the brushes of a generator or motor.

HASP. A U.S. Navy high altitude sounding projectile (rocket) designed for 200,000 feet. It was developed for the Naval Ordnance Laboratory at Silver Springs, Maryland. It was first launched in March, 1957, being fired from a 5-inch naval gun to an altitude of more than 100,000 feet. It was designed to be fired at sea for radar tracking of ejected chaff as a replacement for meteorological balloons. The Hasp was adapted from Army *LOKI* rockets. (See illustration facing Page 155.)

HAWK. A U.S. Army surface-to-air and surface-to-surface (i.e., dual purpose), low-altitude solid-propellant rocket developed by Raytheon (airframe by Northrop). Its dimensions are: 17 feet in length and 14 inches in diameter. (See **missile guided**.) (See also illustration facing Page 218.)

He. Helium.

HE. High Explosive.

HEAD. Pressure expressed as the height of the liquid column necessary to develop that pressure at the base. Its use is particularly convenient for considering the flow of the liquid.

HEADING. (1) The horizontal direction in which a missile or aircraft is pointed, i.e., the direction of its longitudinal axis, usually expressed as an angle measured clockwise from some reference line, such as true north, to the longitudinal axis. (2) In a broader sense, direction.

HEAT BARRIER. The speed at which the heating effect upon a missile, spaceship or other object moving through the atmosphere imposes a limitation upon flight. This effect, which is due to friction heating, is not regarded as a true ceiling, but rather as a range of velocities above which special cooling methods must be devised. The term has the same meaning with respect to the heating problem as the "sound barrier" does with

respect to transonic flight. The heat barrier is generally considered to begin at about Mach 2.

HEAT CAPACITY. The amount of heat necessary to raise the temperature of a system, entity, or substance by one degree of temperature. It is most frequently expressed in calories per degree centigrade. If the mass of a substance is specified, then certain derived values of the heat capacity can be obtained, such as the atomic heat, molar heat, or specific heat. (See **heat, atomic; heat, molecular; and heat, specific.**)

HEAT CONTENT. A thermodynamic property which may be regarded as the total heat of a substance or system, and is defined as the sum of its internal energy plus the product of its pressure and volume, as in the relationship:

$$H = U + PV$$

where H is the heat content, U is the internal energy (see **energy, internal**), P is the pressure, and V is the volume. Heat content is also called the heat function, and the enthalpy. The form in which this concept enters most commonly into calculations is that of changes in heat content when a system changes from one state to another.

HEAT ENGINE. An engine that converts the energy of heat into mechanical energy, such as steam and internal-combustion reciprocating and turbine engines, rocket engines, ramjet engines, etc.

HEAT EXCHANGER. A device used to collect heat from one part of a system (e.g., the **combustion chamber** of a missile) and apply it for a useful purpose in another part of the system.

HEAT IN THE ATMOSPHERE. Heat received from the sun is the primary source of energy for the earth. Some slight amount of heat is received from the earth's interior by virtue of radioactive rocks, but this need not be considered in view of its comparable smallness. Total heat received from the sun, directly below the sun, at the outer limits of the atmosphere (the amount that would be received at the earth's surface if passage were unaffected by the atmosphere and clouds) is very nearly 1.94 gram-calories per sq cm per min. This great quantity of heat is distrib-

uted in such a way that the maximum is received directly below the sun with a decreasing amount received as the distance from the heat equator increases. Tropical areas, for this reason, are warm and polar regions cold.

HEAT OF COMBUSTION. The increase in the **heat content** when one **mole** of a substance undergoes oxidation, whereby the products obtained in complete **combustion** are produced. The heat of combustion is very nearly an additive property; it depends, however, slightly upon molecular constitution, so that isomers do not give identical heats of combustion.

HEAT OF FORMATION. The increase of **heat content** of the system when one **mole** of a substance is formed from its elements. If the physical state of the various elements are not specified they are assumed to be in the state at which they would normally exist at atmospheric pressure and ordinary temperature.

HEAT OF VAPORIZATION. The heat absorbed by a liquid when it vaporizes; the quantity of heat required at a given temperature to convert a unit mass of liquid into vapor.

HEAT OF VAPORIZATION, LATENT. The increase of **heat content** when unit mass, or one **mole**, of a liquid is converted into a vapor at the boiling point, without change of temperature.

HEAT SEEKER. A guided missile or similar device incorporating a heat-sensitive device for homing on heat-radiation machines or installations, such as aircraft engines or blast furnaces.

HEAT SHIELD. The protective structure necessary to prevent destruction of a reentry body incident to **aerodynamic heating**. A material sink may be used to absorb heat, or ablating materials may be used similarly.

HEAT SINK. A device which absorbs heat energy.

HEAT, SOLAR. Heat received from the sun which is the primary source of energy for the earth. On a normal day solar radiation is about 120 Btu/sq ft/hour; maximum anticipated is 360 Btu/sq ft/hour.

HEAT TRANSFER. The heat influx of a high speed missile incident to aerodynamic heating.

HEATER. (1) An electric heating element for supplying heat to an indirectly-heated cathode. (2) A source of heat for a useful purpose.

HEAVISIDE LAYER. Ionosphere.

HEAVY WATER. Water in which the hydrogen of the water molecule consists entirely of the heavy hydrogen isotope of mass two. It is used as a moderator in certain types of nuclear reactors.

HECHT. A German World War II research missile, surface (ramp) launched, propelled by a Walther liquid rocket motor burning hydrogen peroxide and potassium permanganate. The missile was made by Rheinmetall-Borsig. It weighed 308 pounds, was 6½ feet (2.5) meters) long, approximately 10 inches in diameter, with wings of three feet span. It reportedly attained subsonic velocities of 920 feet per second with an engine having a 132 pound (60kg), thrust, burning for 20-25 seconds.

HEDGEHOG. The popular name for the World War II anti-submarine projector Mark X, a British invention adopted and Americanized by the U.S. Navy. It threw a pattern of 24 depth charges in a pattern ahead of a destroyer.

HEF (HIGH ENERGY FUEL). The trade name of the Olin-Mathieson Chemical Corp. for a series of boron-based compounds used as high energy fuels (including HEF-2, HEF-3, and HEF-4). The materials include diborane, pentaborane, decaborane, their alkylated derivatives and some undisclosed lithium compounds.

HELICAL SCANNING. Radar scanning in which a point on the beam traces a helical path in space, the radar antenna revolving and simultaneously changing its angle of elevation.

HELICODROMIC. Having a spiral flight path.

HELICOPTER. A type of aircraft which derives its lift from a powered air vane array mounted above its center of gravity.

HELIOCENTRIC. Measured from the center of the sun; related to, or having, the sun as a center.

HELIUM. Gaseous element. Symbol He. Atomic number 2. Helium has a condensation temperature at 14.7 psia of -452°F , and a density of 0.011 lbs/ft³ at STP. It tends to leak from pneumatic systems; despite excellent seals, it diffuses at joints as does hydrogen. It is sometimes used to pressurize missile fuel tanks, especially when weight is of the greatest importance.

HELIUM, LIQUID FORMS I AND II. Liquid helium undergoes a change in its physical properties at 2.189°K, the so-called lambda-point. The form stable between the critical temperature and the lambda-point is called liquid helium I, and that stable between the lambda-point and absolute zero is called liquid helium II. Since the transformation is one of higher order, without latent heat at the lambda-point, the two liquid forms are never co-existent. The lambda-transformation does not occur in liquid helium with isotopic weight 3.

HENRY. A unit of self or mutual inductance, abbreviation h or hy. (1) The self-inductance of a coil in which an emf of one volt is required to change the current at the rate of one ampere per second. (2) The mutual inductance of two coils, of such geometry and so arranged that an emf of one volt is induced in one if the current in the other is changing at the rate of one ampere per second. The mutual inductance remains unchanged if the roles of the two coils are interchanged, i.e., if the current is changed in the first and the emf is measured across the second. The millihenry (mh), equal to 0.001 hy, is commonly used as a unit of inductance.

HEPTANE. A paraffin hydrocarbon having the chemical composition: C_7H_{16} . It has a boiling point of 208°F , freezing point of -131°F , and a specific gravity of 0.684.

HERCULES. A large and important constellation between Lyra and Corona Borealis. The constellation contains no strikingly bright stars and hence is somewhat difficult to locate. Perhaps the most interesting object in the constellation is the remarkable star cluster which was first noted by Halley in 1714. In

addition to the star cluster there are several **double stars** to be observed with small telescopes, many of them having components of different colors.

HERMES. (1) The code name of a U.S. missile project begun in 1944. It was conducted by the General Electric Company and included both study and actual missile construction. The first flights were at White Sands Proving Ground in 1950. The ultimate objective was to develop an artillery type missile. The program began with firings of captured German V-2 missiles. The first hardware constructed out of the Hermes project was the Hermes A-1, which was similar in appearance to the German Wasserfall anti-aircraft missile, but the A-1 was intended for a surface-to-surface role. Hermes II was to be a surface-to-surface missile weighing about 14 tons. A Hermes A-3 model was also proposed. The Hermes project as originally conceived also included the Hermes C-2, which was to be a three-stage intercontinental missile. The **Bumper** series of firings at White Sands and Cape Canaveral were also part of the Hermes project, as were the RVA-10 firings. Hermes B was a rocket test vehicle for a supersonic ramjet. Hermes C-1 was to be a long range surface-to-surface missile. (2) An asteroid of the solar system which in 1937 came within 400,000 miles of the earth.

HERMETIC INTEGRATING GYROSCOPE. HIG.

HETERODYNE. Two alternating currents of different frequency, when "mixed" in a non-linear impedance device such as a rectifier, generate a current having the sum- and difference-frequencies, either or both of which may be selected by properly tuning or filtering the output. This phenomenon is known as "heterodyne" action, and is put to practical use in the superheterodyne radio receiver circuit. (See **frequency**, **intermediate**.)

HETEROGENEOUS PROPELLANT. Propellant, heterogeneous.

HETEROGENEOUS REACTOR. Reactor, heterogeneous.

HETEROSPHERE. That part of the atmosphere above the homopause (45-50 miles above the surface) as classified by Chapman. (See **homosphere**; **atmosphere**.)

Hf. Hafnium.

Hg. Mercury.

HGE. Handling, Ground Equipment.

HIDYNE. Hydryne.

HIG (GYRO). Hermetically-sealed Integrating Gyroscope. An integrating gyroscope (See **gyroscope**, **integrating**) in which viscous damping replaces the spring restraint of the rate gyroscope. As a result, the restraining force exerted by the viscous damper is proportional to gyroscope precession rate, instead of being proportional to precession displacement, as in a rate gyroscope.

HIGH. (1) An area or region of high atmospheric pressure; (2) a peak in a constant pressure surface.

HIGH ENERGY FUELS. Fuels, high energy.

HIGH FREQUENCY. Any radio frequency between 3,000 and 30,000 kilocycles per second.

HIGH-PASS FILTER. Filter, high-pass.

HINGE MOMENT. In aerodynamics, the moment tending to restore a control surface after it has been displaced from a position of equilibrium. It may be due to a combination of the force of gravity, forces exerted by construction elements (e.g., springs) and the force of the slipstream on the surface. At high Mach numbers the air flow is the principal force contributing to the hinge moment.

HISTOTOXIC ANOXIA. An oxygen deficiency resulting from a decrease of oxygen utilization by the tissues due to poisoning of the tissue cells.

Ho. Holmium.

HODOGRAPH. A curve traced by the end-points of the velocity vectors of a moving particle when they are laid off from a fixed point. If $\mathbf{v} = \mathbf{f}(t)$ is the vector equation of the path of the particle, then $d\mathbf{v}/dt$ is the equation of the hodograph, which sometimes is a straight line when the equation of motion is non-linear, and is thus a useful transformation.

HOHMANN TRANSFER ELLIPSE. In astronautics, a theoretical optimum flight path requiring the least expenditure of fuel for travel from one circular orbit to another in the same gravitational plane. The Hohmann ellipse requires two thrust impulses, one at the beginning of flight and one at the end, with the transfer ellipse between, tangent to both beginning and terminal orbits. It assumes a single gravitational center at one focus, (e.g., the Sun). It is a type of maneuver to be used for travel from Earth to Mars or Venus, (and return), and in essence is the path travelled to intercept one co-planar orbit from another. The Hohmann ellipse can be used for transfer from a close-to-Earth orbit to a more distant orbit, including the Moon in its sweep.

HOLDBACK. A device or mechanism whose function is to retain a missile on its launcher until certain conditions, requisite to successful launching, are met.

HOLD CONTROL. In television, the variable resistor that permits adjustment of the synchronizing oscillator until the latter frequency nearly equals that of the incoming synchronizing pulses. Colloquialism for synchronization controls.

HOLD PARAMETER. A test situation, circumstance, or condition which requires that a testing sequence not proceed until the hold condition is resolved.

HOLLOMAN AIR FORCE BASE. An Air Research and Development Command missile test center situated north of White Sands Proving Ground approximately ten miles southwest of Alamogordo, New Mexico. It is the headquarters of Air Force air-launched missile research. The instrumentation at Holloman is coordinated with that of the Army's White Sands Proving Ground. The **Falcon**, **Shrike**, **Rascal**, **Matador**, **Aerobee**, and other missiles have been tested at Holloman.

HOLY MOSES. A 4.5 inch air-to-surface rocket. (See **rocket**, 4.5 inch.)

HOME. (1) To fly toward a radiation-emitting source, especially a radio transmitter, using the radiated waves as a guide. (2) Self-direction of a missile to its target by guiding on heat radiations, radar echoes, radio

waves, or other phenomena proceeding from, or inherent in, the target.

HOMER. Guidance homing; seeker, target.

HOMING DEVICE. (1) Any transmitter, receiver, or adapter used for homing air vehicles, or used by them for homing purposes; a **homer**. (2) Any device incorporated in a guided missile to home it on a target.

HOMING GUIDANCE. Guidance, homing.

HOMING, INTERFEROMETER. A homing guidance system (see **guidance**, **homing**) in which target direction is determined by comparing the phase of the echo signal as received at two antennas precisely spaced a few wavelengths apart.

HOMING, PASSIVE. A missile which homes on a target without itself radiating employs passive homing. Advantage is taken of radiations from the target or its background which render it distinctive.

HOMING, RADAR. Radar, homing.

HOMING RANGE. The maximum distance at which a **homing device** incorporated into an air vehicle becomes effective, in respect to a target or to a homing station.

HOMING, SEMIACTIVE. Guidance, homing, semiactive; radar illumination.

HOMODYNE RECEPTION. A system of radio reception using a locally generated voltage of the same frequency as that of the incoming carrier. Homodyne reception is sometimes called "zero-beat reception."

HOMOGENEOUS PROPELLANT. Propellant, homogeneous.

HOMOGENEOUS REACTOR. Reactor, homogeneous.

HOMOSPHERE. According to the Chapman classification of the earth's atmosphere, a lower zone (below about 72-80 kilometers or 45-50 miles above the surface in the temperate latitudes), where the major components of the atmosphere (hydrogen, nitrogen, inert gases, carbon dioxide and water vapor) exist in molecular form. Above the upper limit of the homosphere, a level called the "homopause," the heterosphere begins, in which these

gas molecules are highly ionized or dissociated. (See **atmosphere**.)

HONEST JOHN. A free-flight U.S. Army artillery rocket using a pre-set type of guidance. It is powered with a solid-propellant rocket (Hercules Powder Co.), and has a range of about 20-30 miles. It was announced in 1955 as capable of delivering an atomic warhead. The rocket was designed by the Douglas Aircraft Company and Emerson Electronics. Initial tests were completed at White Sands Proving Ground in 1951, and the missile fixed for production in January, 1953. It was 27 feet long, 2.5 feet in diameter (762mm), had a fin span of 109 inches and weighed approximately 6,000 pounds. The missile travels on an unguided trajectory determined by the orientation of the launcher. An anemometer in the launch area gives surface wind effect data. The Honest John is also designated as M-31. (See **missile, guided**.) (See also illustration facing page 218.)

HOPI. A medium-range air-to-surface missile being developed by the Naval Ordnance Test Station at Inyokern, California, designed for carrier aircraft.

HORIZON. (1) The line formed by the apparent meeting of the earth and sky as observed from any point. (2) A plane that runs through the eye of an observer, or a plane parallel to that plane, at right angles to the vertical. (3) A line that indicates such a plane on a flight instrument, as in the artificial horizon.

HORIZON, RADAR, RADIO. The locus on the earth's surface beyond which high frequency electromagnetic signals from a given source cannot be propagated. This limitation arises from the inability of such signals to propagate in other than a straight line and the curvature of the earth, including consideration of diffraction.

HORIZON TRACKER. A device for establishing the vertical by precisely tracking the visible horizon simultaneously in mutually orthogonal directions.

HORIZONTAL. (1) Parallel to the earth's surface, considered as a smooth and uniform sphere. (2) Parallel to the sensible horizon.

(3) Of an airfoil, attached so that it lies perpendicular, or nearly so, to the plane of symmetry of an air or space vehicle, and in a plane parallel, or nearly parallel, to the longitudinal axis.

HORIZONTAL BLANKING. The interruption of the electron beam of a **cathode-ray tube** during horizontal retrace.

HORIZONTAL COORDINATE SYSTEM. The horizontal coordinate system is a system of **spherical coordinates** on the **celestial sphere** which uses the **horizon** as a fundamental plane. Planes perpendicular to the horizon cut out great circles on the celestial sphere known as **vertical circles**. The fundamental direction selected in the fundamental plane is true south. The **azimuth** of a point on the celestial sphere is the angular distance, measured in the plane of the horizon, from the true south direction to the point of intersection of the vertical circle through the object with the horizon. There are several different methods for expressing azimuth, but the astronomical method is to measure azimuth from the south through the west through 360°. The **altitude** of a point on the celestial sphere is the angular distance, measured along the vertical circle through the point, from the plane of the horizon to the point.

The horizontal system of spherical coordinates is frequently referred to as the **altitude-azimuth** system.

HORIZONTAL PLANE. Any plane that has uniform altitude above sea level at all points.

HORN, BICONICAL. An electromagnetic horn, consisting of two cones with their vertices coinciding or adjacent. This horn gives a uniform pattern in a plane perpendicular to the axis and highly directional in any plane containing the axis.

HORN, ELECTROMAGNETIC. Horn radiators are used to obtain directional radiation characteristics which could not be obtained as conveniently with simple antennae. As such directors they are used both with conventional antennae and with wave guides, but in either case they serve to direct the radiation in a pattern from the open end of the horn in a manner determined by the dimensions of the horn. The important dimensions are the horn opening (in terms of wavelength

of the radiation) and the flare angle. While theoretically an infinitely long horn will give a radiation pattern whose angle conforms to that of the horn, those of practical length do not confine the beam to quite this degree. For example a horn with an angle of 15° may give a radiation pattern which spreads 23° .

HORN, EXPONENTIAL. A horn whose cross-sectional area increases exponentially with axial distance. If S is the area of a plane section normal to the axis of the horn at a distance from the throat of the horn, and S_0 is the area of the plane section normal to the axis of the horn at the throat, and m is a constant which determines the rate of taper of flare of the horn, then

$$S = S_0 e^{mx}.$$

HORSEPOWER. (1) Historically, the rate at which a horse can do work. (2) Defined by James Watt as 33,000 ft lbf/min, equivalent to 746 watts.

HORSEPOWER, EQUIVALENT. The approximate equivalent horsepower of a rocket engine is defined as follows:

$$P = \frac{TS}{550}$$

where P is the equivalent horsepower, T is the thrust of the engine in pounds and S is the air-speed in feet per second.

A more exact relationship for the equivalent horsepower of a rocket engine is:

$$P = \frac{R\Delta p}{550 g \rho \eta}$$

where P is the horsepower, R is the rate of flow of propellant, Δp is the pressure difference across the combustion chamber, g is the acceleration of gravity, ρ is the flow density and η is the propulsive efficiency of the engine.

"HOT." (1) A colloquial term meaning highly radioactive. (2) An energized electrical circuit.

HOT-CATHODE TUBE. Tube, hot-cathode.

HOT-WIRE MICROPHONE. Microphone, hot-wire.

HOUD DOG (GAM-77). An air-to-surface missile under development by North

American Aviation for the Strategic Air Command. It is being designed to be carried by a B-52, to be equipped with a nuclear warhead, and to have a range of several hundred miles.

HOURLY ANGLE. (1) The angular distance between two given hour circles on the celestial sphere. (2) The local hour angle. (See Greenwich hour angle, local hour angle, sidereal hour angle.)

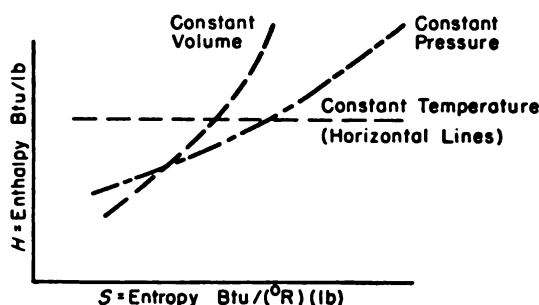
HOURLY CIRCLE. Any great circle on the celestial sphere passing through both celestial poles, used as a line of angular distance or of time measured eastward between the vernal equinox and any given celestial body through which a given hour circle passes. (See right ascension.)

HOWL. Acoustic output of a receiver or sound system due to an undesirable electrical or acoustic feedback at some point in the system.

Hs. A series of German World War II guided missiles developed by the Henschel Flugzeugwerke. Hs117 (also Hs117A1 and Hs 117C) was a subsonic, radio-controlled, guided rocket missile intended as an anti-aircraft weapon. As such it was called the "Schmetterling" and was in large scale production in 1945, reportedly at the Nordhausen underground V-2 factory, in the Harz Mountains. The missile had two liquid rocket motors using 72 kilograms of nitric acid and m-xylydine-triethylamine mixture to deliver 400 kilograms of thrust for 57 seconds. Hs 117H was an air-to-air design similar to the Hs 117. It was shorter and had a span of approximately $6\frac{1}{2}$ feet. Conventional aircraft tail fins were used. It had a forked-nose configuration similar to the Schmetterling and was also radio controlled. The power plant was a solid-fuel rocket engine giving a speed of 550 mph. Hs 293 was a glide-bomb. It weighed 1730 lbs with 1120 pounds of explosive. A rocket motor burning hydrogen peroxide for 10-12 seconds at 1320 pounds thrust carried the missile to 375 mph. The missile was approximately 12 feet long, 19 inches in diameter with 10 feet of wings. It destroyed many Allied ships. Hs293D was to be equipped with a television unit. Hs 294 was an air-to-surface missile developed in 1944, weighing approximately 4780 pounds

with a length of 22 feet, wing span of approximately 13 feet and with a warhead of approximately 3200 pounds. Propulsion was by two hydrogen peroxide rockets developing 2650 pounds of thrust for 10 seconds (missile carried 528 pounds of hydrogen peroxide). Hs295 was another air-to-surface missile developed in 1944. It weighed 4,600 pounds and carried 2,770 pounds of explosive. The missile was 18 feet long, and had a span of about 14 feet. Its propulsive system was the same as the Hs294. Hs296 was identical with the Hs295 but with an armor-piercing warhead. Hs297 was a former identifying number for Hs117. Hs298 was an air-to-air missile developed in 1944, weighing about 250 pounds, carrying some 100 pounds of explosive. It had a sweptback monoplane wing of just under 5 feet span. Propulsion was by a two stage solid propellant (diglycol), rocket.

H-S DIAGRAM. An enthalpy-entropy diagram. Such a diagram is used, for example, to determine thermal efficiencies of engines, compressors and thermal cycles in general. On the H-S diagram, frictionless adiabatic expansions or compressions appear as straight vertical lines. Constant temperature lines appear as straight horizontal lines. See accompanying figure.



Enthalpy-entropy diagram.

H SYSTEM. A radar air navigation system using an airborne interrogator to measure distance from two ground responder beacons. It is similar to *Shoran*, in that it is a hyperbolic position finding system.

HTV (HYPERSONIC TEST VEHICLE). Specifically, a two-stage vehicle about 12 feet long developed by the Curtis Wright Aerophysics Development Corporation to attain 5,000 mph (Mach 7), with an acceleration of 100 G. It was first fired in November, 1954,

at Holloman Air Missile Development Center. The first stage consisted of 7 bundled 9-inch diameter solid-propellant rockets, and the second stage was 4 rockets of the same kind (WASP I). After the second stage burn-out, the tail fins are blown off, and the second stage falls in a flat spin at 100 mph. (See *missile, guided*.)

HULCHER. A slow frame-speed camera used for missile-launching documentary and engineering sequential-camera coverage. The film size is 70 mm. The Hulcher is normally mounted on a tripod. The frame size may be either $2\frac{1}{4} \times 5$ inches or $2\frac{1}{2}$ inches. The rate of exposure may be varied from approximately 10 to 25 frames per second. Lenses of 7 and 12 inch focal length are used. Shutter speeds vary with the frame speed from $\frac{1}{680}$ th to $\frac{1}{1700}$ th second. Other speeds from $\frac{1}{240}$ th to $\frac{1}{3600}$ th can be obtained by changing shutters. This camera can record coded timing signals of 100 and 1000 pps.

HUMAN ENGINEERING. The art or science of designing, building, or equipping an aircraft or space vehicle to the anthropometric, physiological or psychological requirements of a person.

HUMIDITY. The amount of water vapor in the air. (1) *Absolute Humidity* is the amount of water vapor in the air in quantitative terms, e.g., pounds of water per pound of dry air. (2) *Relative Humidity* is the ratio of the amount of water vapor in the air to the maximum amount which air at any given temperature can retain without precipitation. Relative humidity is usually expressed in terms of percent. The temperature at which relative humidity is measured is necessary to give meaning to the measurement.

HUNDRED PERCENT ZONE. In ballistics, the area within which all impacts are contained.

HUNTING. A condition of instability, as for example in a mechanical system or an automatic-control system, which is essentially an uncontrolled oscillation due to excessive feedback or underdamping. The oscillator swings about a predetermined reference point without seeming to approach it.

HURRICANE. A term applied to extra-tropical storms in the Atlantic Ocean. Over

all oceans, near the equator, with the exception of the South Atlantic, there develop occasionally tropical cyclones which are intense vortices covering relatively large areas. As they move away from the equator they usually intensify. Surface pressure in a hurricane is very low at the center or eye of the storm, but rise rapidly outward toward the periphery. Because of the large pressure gradient, winds are of high velocity, blowing counter-clockwise in the northern hemisphere and clockwise south of the equator.

HVAP. High-velocity, armor-piercing rocket.

HVAR. High-velocity aircraft rocket.

H-VECTOR. The vector representing **magnetic field**; the term being used especially in regard to **electromagnetic waves**, where both electric and magnetic fields are involved. In free space the H-vector of an electromagnetic wave is perpendicular to the direction of propagation, and also to the **E-vector** representing the associated **electric field**.

HYBRID ROCKET. Rocket, hybrid.

HYDRAZINE. (1) A chemical compound having the formula N_2H_4 , used as a propellant. It has a relatively high specific impulse, a boil-

ing point of 236°F, freezing point of 35°F, and a density of 68°F of 1.01 gm/cm³. (2) One of a class of chemical compounds in which one or more of the hydrogen atoms of hydrazine (1) are replaced by organic radicals.

HYDRAZINE HYDRATE. A chemical compound having formula $N_2H_4 \cdot H_2O$, which is a possible propellant. It is **hypergolic** with nitric acid, which is usually used as its oxidizing agent. It is spontaneously ignited by hydrogen peroxide. Its computed specific impulse is 218 lb-sec/lb at a chamber pressure of 300 lb/sq. in. area, and a chamber temperature of approximately 4000°F.

HYDRAZONE. A compound formed by reaction of a hydrazine (2) with an aldehyde or

ketone. The carbonyl group of the aldehyde or ketone reacts with hydrogen atoms of the hydrazine, eliminating water. Hydrazones are used in high energy fuels, such as **Hydyne**.

HYDRODYNAMICS. The study of the dynamics of fluid motion, especially the steady motions of an incompressible, inviscid fluid.

HYDROGEN. Gaseous element. Symbol H. Atomic Number 1.

HYDROGEN PEROXIDE. A chemical compound having the formula H_2O_2 . It can be readily decomposed to yield water and oxygen, the latter being thus made available for oxidation of fuels. This decomposition reaction is exothermic, and the heat evaporates part of the water, this process adding to the propulsive efficiency of the system. Sometimes hydrogen peroxide is used as a **monopropellant** for rocket motors. In such applications it is decomposed by a catalyst (e.g., calcium permanganate, potassium permanganate, manganese dioxide, platinum, silver and other materials). It has a chamber pressure of 300 per sq. in. area, a 1800°F chamber temperature and a 715°F exit temperature. Its specific impulse depends upon the concentration as may be seen from the following comparative figures:

Properties of Hydrogen Peroxide

	100% Concentration	87% Concentration
Exit velocity	4710 ft/sec	4065 ft/sec
Specific Impulse	146 lb-sec/lb	126 lb-sec/lb
Chamber temperature	1794°F	1216°F
Exit temperature	714°F	379°F

Hydrogen peroxide (100% concentration) has a melting point of 29°F, boiling point of 306°F, and a density at 32°F of 1.46.

HYDROMETEORS. Condensation products of atmospheric processes often appear as hydrometeors or bodies of falling liquid and solid water (See **rain**, **snow**, **drizzle**, **sleet**, **hail**, **snow pellets**, **hail (small)**.)

HYDROPHONE. An acoustical device used to detect sounds transmitted through water. It is essentially an electroacoustical transducer which responds to water-borne sound waves by producing equivalent electrical waves.

HYDROPHONE, DIRECTIONAL. A hydrophone the response of which varies signifi-

cantly with the direction of the sound incidence.

HYDROPHONE, LINE. A directional hydrophone (see **hydrophone, directional**) consisting of a single straight line element, or an array of continuous or spaced electroacoustic transducing elements disposed on a straight line, the acoustic equivalent of such an array.

HYDROSPHERE. In geodesy, that portion of the surface of the earth composed of water. (See also **lithosphere**.)

HYDROSTATICS. The study of fluids in equilibrium.

HYDYNE. A trade name of the Rocketdyne Division of North American Aviation Corporation for their propellant mixture combining **hydrazine** and an additive, (60% unsymmetrical dimethyl hydrazine and 40% diethylenetriamine). It was compounded originally for the Army Ballistic Missile Agency **Jupiter-C** vehicle. It was also identified as U-DETA.

HYGROMETER. An instrument used in meteorology for the measurement of humidity in the air. There are a large number of such instruments, including: The *chemical hygrometer* which uses a chemical substance to absorb the water from a known volume of air; The *wet-and-dry bulb hygrometer* which consists of two thermometers, one of which is cooled by a damp wick immersed in a water reservoir, the other thermometer bulb is exposed to the air, "dry" and the difference between the two temperatures can be calibrated to values of relative humidity; The *hair hygrometer* which uses a stretched hair which changes its tension with variations in humidity; The *dew-point hygrometer* which contains a volatile liquid which is evaporated by an aspirated air stream until the apparatus has been cooled to the dew point, shown by appearance of water on the metal surface of the apparatus.

HYGROSCOPIC. Descriptive of a material which readily absorbs and retains moisture

HYKON. One of a series of aerial cameras manufactured by the Hycon Manufacturing Company, Pasadena, California. The Hykon K-20 is a 20 pound aerial camera, using 9 x 9 inch film and a 6 inch metrogen lens. It has

built-in image motion compensation, making it suitable for use in aircraft or reconnaissance missiles.

HYPERBARISM. A disturbed condition in the human body arising from an ambient gas pressure or atmospheric pressure that is higher than the pressure within the body tissues, fluids, and cavities, as may occur in a sudden descent from a high to a low altitude.

HYPERBOLA. A conic section obtained by a plane cutting both **nappes** of a right circular **conical surface**. It is the locus of a point which moves that the difference of its distances from two foci is a constant. Its **eccentricity** is greater than unity.

The standard equation may be taken as

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1.$$

The curve is a central conic for it is symmetric about both the *X*- and *Y*-axes when placed in this standard position and the coordinate origin is its center. The transverse axis, coincident with the *X*-axis, is of length $2a$; the conjugate axis, along the *Y*-axis, has length $2b$ ($b < a$). The distance from the center of the hyperbola to either focus is $\sqrt{a^2 + b^2}$; the eccentricity, $e = \sqrt{a^2 + b^2}/a$; the length of the latus rectum is $2b^2/a$; the equations for the directrices are $x = \pm a/e$, the same as for the ellipse. The distance from any point on the hyperbola to a focus is a focal radius and the difference between any two focal radii equals $2a$. The lines $y = \pm bx/a$ are asymptotes to the hyperbola. If the lengths of the transverse and conjugate axes become equal ($a = b$), the curve is an equilateral or rectangular hyperbola.

HYPERBOLIC FUNCTION. Combinations of $e^{\pm z}$ with properties similar to those of the trigonometric functions. They are defined by:

$$\sinh z = \frac{1}{2}(e^z - e^{-z}) = z + \frac{z^3}{3!} + \frac{z^5}{5!} + \cdots;$$

$$\cosh z = \frac{1}{2}(e^z + e^{-z}) = 1 + \frac{z^2}{2!} + \frac{z^4}{4!} + \cdots;$$

$$\tanh z = \frac{\sinh z}{\cosh z};$$

$$\coth z = 1/\tanh z;$$

$$\operatorname{sech} z = 1/\cosh z;$$

$$\operatorname{csch} z = 1/\sinh z.$$

For real z , their geometric representation is related to the **hyperbola** as the trigonometric functions are related to a **circle**. The two sets of functions are connected by the equations

$$\sinh iz = i \sin z;$$

$$\cosh iz = \cos z;$$

$$\tanh iz = i \tan z.$$

HYPERBOLIC GUIDANCE. Guidance, hyperbolic.

HYPERBOLIC NAVIGATION. Navigation, hyperbolic.

HYPERBOLIC PROBE. An instrumental (or manned) space vehicle which escapes the earth-moon field and enters into interplanetary space. Because the escape path very closely represents a hyperbola, the vehicle is named accordingly. Hyperbolic probes are classified in two major groups. The first of these groups, the interplanetary probes, is divided into three subgroups; (1) Martian probes, (2) Venusian probes, (3) Solar probes. The second group, that of **circumplanetary satellites**, is divided into two subgroups: (1) Martian satellites, (2) Venusian satellites. (See table in article on **instrumental vehicles for space research**.)

HYPERBOLIC VELOCITY. The velocity of a body whose orbit is a hyperbola.

HYPERFOCAL DISTANCE. The distance beyond which all objects are in focus for a given lens. It marks the near limit of focus in the depth of field. It is given by the relationship:

$$H = \frac{F^2}{fd_{cc}}$$

where H is the hyperfocal distance, F is the focal length of the lens, f is the aperture setting of the lens, and d_{cc} is the diameter of the circle of confusion.

HYPERFREQUENCY WAVES. Microwaves, or electromagnetic waves with wavelengths of from one centimeter to one meter (i.e., 300-30,000 megacycles per second).

HYPERGOLIC (SELF-IGNITING). Capable of spontaneous ignition on contact.

HYPEROXEMIA. A condition in which the oxygen content of the blood exceeds that normally existing at sea level.

HYPEROXIA. Any excess of the oxygen tension in the atmosphere or in an animal body above that normally existing at sea level.

HYPERSONIC. Having a high velocity. In common usage, the term is applied to velocities greater than Mach 5. The hypersonic region does not differ in its flow pattern from the supersonic, in the way that the latter does from the subsonic region. That is, there is no essential difference between flow at Mach 2 and Mach 10, except that at very high Mach numbers, the Mach angle is so small that the shock wave will be almost parallel with the direction of motion. At hypersonic speeds bodies must be blunt-nosed to reduce heat transfer rates.

HYPERSONIC TEST VEHICLE. A 5000 m.p.h. rocket developed by the Aerophysics Development Corporation of Santa Barbara, California. It is 12 feet long, with the first stage consisting of 7 small 9-inch solid propellant rockets bundled together to form a package some 5 feet long. The second stage consisted of 4 similar rockets also bunched concentrically. The rocket was developed under the U.S. Air Force Air Research and Development Command. It attained Mach 7 during firings at Holloman Air Development Center, Alamogordo, New Mexico. The first firing was in November 1954. It has a take-off acceleration of 100 G.

HYPERTHERMANTIC. Pertaining to the heating phenomena associated with hypersonic flight.

HYPOBARISM. A condition in which the gas pressure within the body tissues, fluids, or cavities is greater than the surrounding gas or atmospheric pressure, as may occur in a sudden decrease of external pressure.

HYPOXEMIA. An abnormal bodily condition or disease brought on by **hypoxia**.

HYPOXIA. Oxygen deficiency in the blood, cells, or tissues.

HYSOMETER. An instrument used to determine elevations from values of atmospheric pressure obtained through observation of the boiling point of liquids.

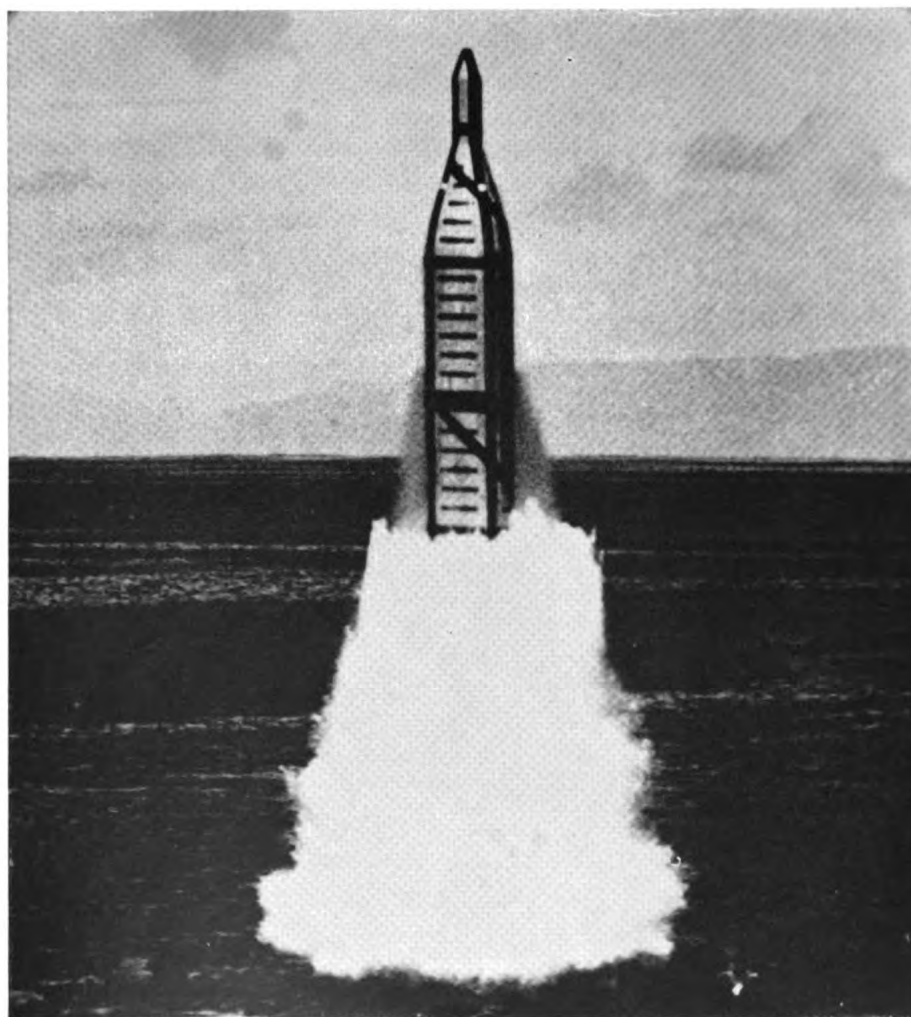
HYSTERESIS. In general, the phenomenon exhibited by a system whose state depends on its previous history. In most usages the term

connotes non-return to a previous condition. Thus *magnetic hysteresis* is the residual magnetic induction remaining in a material after changes in magnetic field intensity. *Electric hysteresis* is a somewhat analogous phenomenon exhibited by dielectrics in an electric field.

In *elastic hysteresis*, the strain or deformation in a material does not follow changes in stress. Finally, in communications systems, the term hysteresis denotes the lag between the response of a unit or system and changes in signal intensity.



PETREL missile mounted on a naval airplane. (*U.S. Navy Photograph*)



Operation Pop-Up. A program concerned with the U.S. Navy POLARIS missile test program. This photograph shows a test vehicle as it clears the surface of the ocean seconds after leaving a launching tube housed in a stationary cylinder beneath the surface. (*U.S. Navy Photograph*)



One of the Navy's type aircraft rockets, the anti-tank RAM is shown after being fired from a carrier F4U Corsair, operating in the Korean War Zone, May 8, 1951. (*U.S. Navy Photograph*)



Released many miles from its target, the U.S. Air Force RASCAL'S powerful rocket engine drives the missile at supersonic speeds. (*U.S. Air Force Photograph*)

I

I. (1) Areal moment of inertia (I). (2) Moment of photographic plate (i). (3) Van't Hoff factor (i). (4) Ionic strength (I). (5) Vapor pressure constant (i). (6) Nuclear mechanical magnetic moment, or spin quantum number (I). (7) Radioactivity, initial (I_0), at time t (I). (8) Candlepower or luminous intensity (I). (9) Integration constant for free energy (Gibbs) equation (I). (10) Total electron emission (saturation) (I_s). (11) Conduction current (I). (12) Average current (I_{av} , I). (13) Convection current (I). (14) Effective rms current (I). (15) Instantaneous current (i or I). (16) Maximum current (I_{max} or I_m). (17) Peak current (I_p , I , I_{pk}). (18) Saturation current (I_s). (19) Imaginary unit, $\sqrt{-1}$ (i). (20) Iodine (I). (21) Impulse (I). (22) Average impulse (I_{av}). (23) Specific impulse (I_{sp}). (24) Total impulse (I_t).

I & M. Installation and Maintenance.

IAF. International Astronautics Federation.

IAS (INSTITUTE FOR AERONAUTICAL SCIENCES). A U.S. professional society for the promotion of aeronautical matters.

IBDA. Indirect bomb damage assessment.

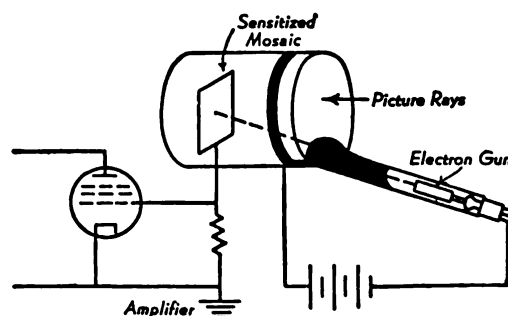
ICAO. International civil aeronautics organization.

ICBM. Intercontinental ballistic missile.

ICE CRYSTAL CLOUDS. At temperatures below about 15°F water vapor changes to solid water directly without the intermediate liquid-water stage. Cloud particles form directly on sublimation nuclei as ice crystals, and such clouds are then composed of ice-crystal particles. Cirro-form clouds are of the ice-crystal group.

ICFATCMUTAL. "Individual is cleared for access to classified material up to and including."

ICONOSCOPE. A camera tube (see **tube, camera**) in which a high-velocity electron beam scans a photoactive mosaic which has electrical storage capability. This form of tube is used in television. The scene to be transmitted is focused on the mosaic consisting of very many minute photoelectric cells. They may be formed by various processes, such as treating a sheet of mica with silver oxide, and reducing the oxide to silver in such a way as to form many little globules of silver, which are then photosensitized by treatment with cesium or similar metal. The scene falling upon this mosaic causes the photosensitive particles to emit electrons proportional to the light falling upon them. In the process the particles of silver are charged, to be periodically discharged by the scanning beam of electrons which is swept back and forth across the picture until every particle has been touched in sequence. This electron beam restores the negative charge which the photoelectric action had removed. This sudden restoration of charge gives a pulse of current in the circuit connected to the other plate of the little condenser, i.e., the backing conductor. This pulse magnitude depends upon how many electrons had to be restored and hence upon the brilliance of the picture at that point. Since the charges are restored in sequence there will be a sequence of pulses in the output circuit which represents the orderly dissection of the picture into minute parts for transmission. (See figure.)



Iconoscope.

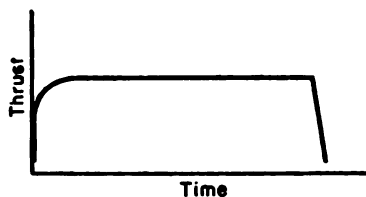
ICONOLOG. An optical instrument for the reading of 35mm **theodolite** film in use at the Naval Ordnance Test Station. It will read about 100 frames per hour, and direct the automatic punching of IBM cards according to the data read. An Iconolog is also in use at the Naval Air Missile Test Center, Point Magu, California.

ICUS. Inside Continental United States.

ICW. *Interrupted continuous wave.*

IDA. Institute for defense analysis.

IDEAL BURNING. Burning of solid propellants so that the **thrust** and **chamber pressure** remain essentially constant throughout the **burning time**. (See figure.) (See also **progressive burning**; **regressive burning**.)



Ideal burning.

IDEAL GAS LAW. A relationship between the pressure, volume and absolute temperature of a gas in which changes in the first two (with the third constant) are inversely proportional, and changes in one of the first two (the second constant) are directly proportional to changes in absolute temperature. This law may be stated in the form:

$$\frac{p_1 v_1}{T_1} = \frac{p_2 v_2}{T_2}$$

or $pv = RT$, where R is the **gas constant**. This law is not obeyed exactly by any real gas, nor is R exactly the same for different gases. However, the law is sufficiently close for approximate calculations, provided the temperature of the gas is not near its critical value.

IDEAL ROCKET. A theoretical rocket motor having a velocity equal to its exhaust velocity.

IDEAL THERMODYNAMIC EFFICIENCY. A rocket motor design parameter defined by the expression:

$$\eta_i = 1 - (p_e/p_c)^{\frac{\gamma-1}{\gamma}}$$

where η_i is the ideal thermodynamic efficiency, p_e is the exhaust pressure, p_c is the chamber pressure, and γ is the ratio of specific heats. Actually, the concept has limited significance in rocket motor design as a measure of operational efficiency since a high η_i is dependent upon a high γ which is inconsistent with low propellant consumption, an important operational factor.

IDEAL TRAJECTORY. An approximation of the true flight of a projectile obtained by some refinements of the vacuum (or "elliptical") trajectory. It is obtained by replacing the missile by a particle having the same mass, velocity, direction of travel and position as the missile at burn-out. This particle is subject to no forces other than gravity and air drag. The air drag is assumed to be the same function of velocity as the drag of the missile with zero angle of attack. The ideal trajectory is sometimes called the particle trajectory. The ideal trajectory lies in the vertical plane containing the velocity vector at burnout. It is shorter than the vacuum trajectory as a result of drag, and its motion is subject to a constant velocity drop, as is the missile. Also, the descending branch of the ideal trajectory is steeper than the ascending branch because of the velocity drop. (See also **trajectory**.)

IDENTIFICATION, FRIEND OR FOE (IFF). A method of automatic identification of an aircraft or ship. A coded challenging transmission received by a correctly-adjusted receiver in a friendly vessel causes the automatic transmission of an identification signal, usually on another frequency.

IF. Intermediate frequency.

IFF. Identification, friend or foe.

IFLTT. Intermediate focal length tracking telescope.

IFRB. International frequency registration Board.

IG. Inertial Guidance.

IGNITER. A device used to initiate combustion; specifically a device which initiates burning of a fuel mixture or a propellant in

a ramjet or rocket combustion chamber respectively. A **pilot-burner** in a ramjet may serve the same purpose.

IGNITION, MULTISTAGE. An ignition system in a ramjet in which a portion of the fuel (propellant) is ignited, and the hot combustion products are used to ignite other portions of the fuel, the process continuing in stages until the fuel charge is fully utilized.

IGNITION SYSTEM. The system for igniting the **propellant** of a rocket engine.

IGNITRON. An **electron tube** of the mercury-arc type having a special starting principle. The tube consists of a mercury pool, to serve as **cathode**, and an **anode** for the main part of the circuit and an auxiliary electrode, the igniter, which dips into the mercury pool.

IGOR. An abbreviation for Intercept Ground Optical Recorder. It is simply an elaborate tracking telescope, being essentially an extension of a **theodolite**. It uses 35 mm. film, and can record timing. It is used for long-range missile tracking.

IGY. International geophysical year.

IGY SATELLITE. Artificial satellite.

IIP. Instantaneous impact prediction.

IM. Interceptor missile.

IM-70. Interceptor Missile 70; the U.S. Air Force version of **Talos**.

IM-99. Interceptor Missile 99; the U.S. Air Force **Bomarc**.

IMAGE POINT. A point beneath the surface of the earth, equal in depth to the height of an exploding nuclear weapon. The image point is used in calculations as the origin of radiating reflected shock.

IMITATIVE DECEPTION. Deception, imitative.

IMO. International Meteorological Organization.

IMPACT. The action of two bodies in collision, whereby the velocity of one or both bodies is changed. In the case of direct impact, the velocity of the moving bodies is in

the direction of the normal (perpendicular) to the bodies at the point of contact. Otherwise the impact is oblique. The impact is central when the centers of gravity of the two bodies lie on the line of impact (normal to the bodies at the point of contact). The momentum of a body is its mass multiplied by its velocity. A law of impact is that the sum of the momenta of the two masses before and after impact is the same.

IMPACT AREA. (1) The area in which a missile and/or its payload strikes the surface of the earth. The Intended Impact Area is the target area. (2) The area along the line of flight where jettisoned parts will strike the surface of the earth after separation from the missile at staging (e.g., stage-one impact area; booster rocket impact area).

IMPACT DETECTOR. Detector, impact.

IMPACT FUZE. Fuze, impact.

IMPACT POINT. (1) The point at which a missile and/or its payload strike the surface of the earth. (2) The point along the line of flight where jettisoned parts strike the surface of the earth or sea after stage separation.

IMPACT POINT, NOMINAL. A fixed location in each **impact area**, chosen for planning purposes in connection with instrumentation systems. This point when chosen will remain fixed throughout the test program.

IMPACT PREDICATOR. A scheme or mechanism for continuously estimating the coordinates of a missile **impact point**, usually based on present position and velocity information obtained by optical or electronic tracking. Equations are solved and trajectories and time-to-go are estimated by ground computers. The information may be used by the range safety officer to destroy the missile, or for an early assessment of performance to assist in making a decision for firing the next round.

IMPACT PRESSURE. In aerodynamics, the sum of the **static** and **dynamic pressure**.

IMPEDANCE. The complex ratio of a force-like quantity (force, pressure, voltage, temperature or electric field strength) to a related velocity-like quantity (velocity, volume velocity, current, heat flow, or magnetic field

strength). The terms and definitions under the term "impedance" pertain to single-frequency quantities in the steady state, and to systems whose properties are independent of the magnitudes of these quantities. These quantities can be represented mathematically by complex exponential functions of time. Under these conditions the factors involving time cancel out in the ratios called for, leaving complex numbers independent of time. Solutions based on complex exponential functions under these conditions give the solution for real sinusoidal oscillations. Because of the similarity of electrical, mechanical, and acoustical transmission theory, the same terminology is used in the three cases. Where confusion is likely to occur, the proper term should be prefixed to the general term, e.g., acoustic transfer impedance. For example, while acoustics is a branch of mechanics, it is found convenient to distinguish an acoustic system from a mechanical one whenever elastic wave motion is an essential feature. While a strict application of the impedance concept implies the restrictions given here, it is common practice to extend the term "impedance" to situations involving nonsinusoidal quantities or nonlinear systems. Such extensions should be accompanied by an explanatory statement. (See also **impedance, acoustical**; **impedance, electrical**; **impedance, matching**.)

IMPEDANCE, ACOUSTICAL. The complex quotient of the pressure applied to a system by the resulting volume current. The unit is the acoustical ohm.

IMPEDANCE COIL. A reactance or choke coil used to limit the flow of current in a circuit.

IMPEDANCE, ELECTRICAL. The ratio of the effective value of the potential difference between the terminals to the effective value of the current, there being no source of power in the portion of the circuit under consideration. The unit is the abohm.

IMPEDANCE, MATCHING. Two impedances are matched when they have the same magnitude and the same phase angle; the transmission of power between them is thus maximized.

IMPEDANCE, MECHANICAL RECTILINEAL (MECHANICAL IMPEDANCE).

The complex quotient of the alternating force applied to the system divided by the resulting linear velocity in the direction of the force at its point of application. The unit is the mechanical ohm.

IMPEDANCE, MECHANICAL ROTATIONAL (ROTATIONAL IMPEDANCE). The complex quotient of the alternating torque applied to the system divided by the resulting angular velocity in the direction of the torque at its point of application. The unit is the rotational ohm.

IMPEDANCE OF FREE SPACE. The impedance of free space, as presented to a propagated electromagnetic wave, is 377 ohms. Air is practically equivalent to free space. The velocity of propagation of electromagnetic waves in air is reduced only about 1/3000th below that of free space.

IMPEDANCE, SOURCE. Source impedance.

IMPELLER. A revolving turbine-like mechanism designed to impart motion (velocity and pressure) to a fluid coming in contact with it. It is a device within a system to produce fluid flow. In the most common usage, a turbine differs from an impeller in that the flow from the former exhausts beyond the system.

IMPINGING-STREAM INJECTOR. In a liquid-propellant rocket engine, a device that injects the fuel and oxidant into the combustion chamber in such a manner that the streams of fluid intersect one another.

IMPLODE. A verb describing the violent shattering of a vessel or container in which the internal pressure is less than the external, e.g., in a highly-evacuated **cathode-ray tube** when the glass envelope is suddenly broken. Due to the atmospheric pressure against all sides of the tube, the glass moves inward with tremendous force.

IMPLOSION. Collapse. (See **implode**).

IMPONDABILITY. Weightlessness.

IMPULSE. A vector quantity defined by the time integral of the force **F** acting on a particle over a fine interval, for example,

$$\int_a^b \mathbf{F} dt$$

for the interval from t_1 to t_2 . The impulse-momentum theorem states that the impulse equals the change in momentum experienced by a particle during the corresponding time interval.

IMPULSE, AIR SPECIFIC. Specific impulse, air.

IMPULSE, EFFECTIVE. The effective impulse is equal, by specification definition, to that portion of the thrust-versus-duration curve between the 90 percent-of-rated-thrust ordinates on a plot made of the complete firing of a rocket engine.

IMPULSE, FUEL SPECIFIC. Specific impulse, fuel.

IMPULSE MANEUVER. Maneuver.

IMPULSE, OVER-ALL SPECIFIC. Specific Impulse, over-all.

IMPULSE-REACTION TURBINE. A turbine which employs the principles of both impulse and reaction. (See **impulse turbine: reaction turbine**.) Normally the reaction increases towards the rotor blade tips, and becomes negligible at the blade roots.

IMPULSE, SPECIFIC. Specific impulse.

IMPULSE, SPECIFIC—IDEAL OR THEORETICAL. Specific impulse, ideal or theoretical.

IMPULSE, TOTAL. In jet propulsion usage, the product of the average thrust (in pounds), developed by the engine and the burning time (in seconds).

IMPULSE TURBINE. A turbine driven chiefly by the impulse of a fluid, which is flowing at relatively low pressure and high velocity through the rotor blades.

IMPULSE-WEIGHT RATIO. A measure of the efficiency of propulsive systems that is used to compare **propellants**. It is defined as the ratio of total impulse to take-off weight, and may be found from the expression:

$$I/W = \frac{Ft}{W}$$

where I/W is the impulse-weight ratio, F is the thrust, t is the time of burning of the motor,

and W is the total weight of the rocket at take-off.

In. Indium.

INCIDENCE ANGLE. (Angle of Incidence.)

INCLINATION. (INCLINATION ANGLE.) An angle between two lines or two planes, as the angle between the plane of a **satellite** orbit and the plane of the **ecliptic**.

INCLINOMETER. An instrument for measuring angles. As applied to missiles, and vehicles traveling in air or space, it is a device to measure **attitude** with respect to the horizon.

INCOMPRESSIBLE FLUID THEORY. In aerodynamics, the theory that the density of the air does not change appreciably during the flow process. This assumption is adequate for flow velocities of less than 400 miles per hour. At higher speeds the compressibility of the air must be considered, and the density of the fluid (air) must be introduced into computations.

INDEPENDENT COMPONENTS. In reliability studies, those components whose reliability is independent of the remainder of the system: e.g., no functional or environmental interaction.

INDICATED ALTITUDE. Altitude as shown by **altimeter**. With a pressure, or barometric, altimeter it is altitude as shown by the reading uncorrected for instrument error and uncompensated for variations from standard air condition.

INDICATOR DIAGRAM. A P-V diagram.

INDIRECT BOMB DAMAGE ASSESSMENT (IBDA). The means, usually independent of the guidance system, for confirming the detonation of a nuclear explosion, its position with respect to the target and the resulting damage.

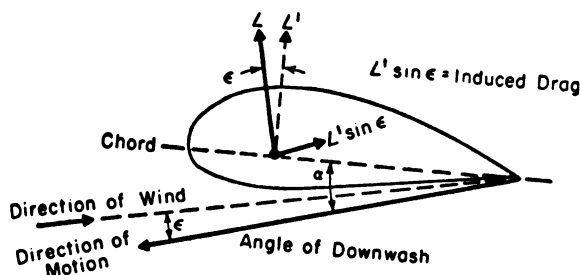
INDIRECT SCANNING. Scanning, indirect.

INDITRON. A neon-glow tube used in counting operations. It has an arrangement of small number-shaped neon tubes in depth down the axis of symmetry of the cylindrical

glass tube. Conductors lead to each of these tubes, and any one of them can be lit. They are used as numerical indicators, for example nine of them may indicate any digit from 1 to 9 (0 if none are lit). Because all the tubes are glass, only the neon tube which is lit shows distinctly through the transparent crown of the outer tube. The inditron is no larger than an ordinary radio tube in diameter, and one of them can replace a bank of 9 ordinary indicators to represent the numbers from 0 to 9.

INDIUM. Metallic element. Symbol In. Atomic Number 49.

INDUCED DRAG. The increased drag due to a component of the lift acting in the direction of motion. It is caused by downwash over the airfoil tips, which deflects the relative wind by the amount of the downwash angle with respect to the direction of motion. In the figure, induced drag is $L' \sin \epsilon$.



Induced drag.

INDUCED NOISE. A type of tube noise due to induced voltages in the electrodes, caused by ultra-high frequency components of the random space charge.

INDUCED ROLL. Missile roll motions resulting from induced rolling moments.

INDUCED ROLLING MOMENTS. The moment resulting from aerodynamic forces which acts to roll a missile during flight at angles of attack other than zero. It is encountered under conditions of large lateral accelerations, particularly when large angles of attack are used. These induced moments may be attributed to: (a) Wing tip effects (b) Wing root effects (c) Separation effects on body and wing surfaces (d) Sweepback effects (e) Downwash effects or interference on the tail surface. In general, anything which affects the symmetry of the missile during a

lateral maneuver at large angles of attack is apt to produce rolling moments.

INDUCED VELOCITY. (1) A velocity increase over that of the free-air stream caused by the presence of a body in the stream. (2) The velocity of the induced flow through a rotor.

INDUCTANCE. (1) That property of an electric circuit or of two neighboring circuits which determines the electromotive force induced in one of the circuits by a change of current in either of them. (2) That coefficient which, when multiplied by 2π times the frequency, gives the positive imaginary part of the electrical impedance. The unit is the abhenry.

INDUCTION COMPASS. An instrument which indicates direction by the generation of current in a coil revolving in the earth's magnetic field.

INDUCTIVE FEEDBACK. Feedback of energy from the plate circuit of a vacuum tube to the grid circuit through an inductance or by means of inductive coupling.

INDUCTIVE LOAD. An electrical load whose impedance has a positive imaginary component; i.e., it acts like a combination of resistance and inductance, as contrasted with resistance and capacitance.

INDUCTOR. (1) A device the primary purpose of which is to introduce inductance into an electric circuit or network. (2) A conductor or bundle of conductors on an electric machine in which voltage is induced by the cutting of lines of flux, e.g., the main conductors along the surface or in the slots of a generator armature.

INERTANCE. In an acoustical system that coefficient which, when multiplied by 2π times the frequency, gives the positive imaginary part of the acoustical impedance. The unit is the gram per centimeter to the fourth power.

INERT EXPLOSIVE. An explosive which can withstand severe environmental and handling loads without danger of spontaneous detonation.

INERTIA. A property manifested by all matter, representing the resistance to any alteration in its state of motion. Mass is the

quantitative measure of inertia. Thus inertia is a measure of the reluctance of a body to change its translational and rotational velocities (including changes from zero). For translational motion inertia and mass are equivalent.

INERTIA CONSTANT. In electrical machines, the energy stored in the rotor when operating at rated speed. It is expressed in kilowatt-seconds per kva rating of the machine.

$$H = \frac{0.231 WR^2 n^2 \times 10^{-6}}{Rat.}$$

Where H is the inertia constant (in kw-sec/kva), WR^2 is the moment of inertia in lb-ft², n is the speed in rpm, and Rat is the rating of the machine in kva.

INERTIA, MOMENTS AND PRODUCTS OF. In the general case of the motion of a particle or aggregate of particles with respect to a single fixed point, the angular momentum can be written as having three components with respect to a coordinate system based at the fixed point.

$$H_x = \omega_z \Sigma m_i (y_i^2 + z_i^2) - \omega_y \Sigma m_i x_i y_i - \omega_z \Sigma m_i x_i z_i$$

$$H_y = -\omega_z \Sigma m_i x_i y_i + \omega_x \Sigma m_i (x_i^2 + z_i^2) - \omega_x \Sigma m_i y_i z_i$$

$$H_z = -\omega_x \Sigma m_i x_i z_i - \omega_y \Sigma m_i y_i z_i + \omega_y \Sigma m_i (x_i^2 + y_i^2)$$

where ω_x , ω_y , ω_z = components of angular velocity, m_i = mass of i th particle, x_i , y_i , z_i = coordinates of i th particle.

The terms $\Sigma m_i (y_i^2 + z_i^2)$, $\Sigma m_i (x_i^2 + z_i^2)$, $\Sigma m_i (x_i^2 + y_i^2)$ are called moments of inertia with respect to the x , y , and z axes, respectively, and are symbolized by I_{xx} , I_{yy} and I_{zz} .

The terms $\Sigma m_i x_i y_i$, $\Sigma m_i x_i z_i$, etc., are called the products of inertia and are symbolized by I_{xy} , I_{xz} , etc.

For a continuous rigid body the summations are replaced by integrals over the volume of the body. In a rigid body, it is sometimes easier to choose coordinate axes, called moving axes, which are fixed in the body. There always exists one set of such axes, called principal axes, such that the products of inertia vanish and the angular momentum can be expressed in terms of the moments of inertia alone. The moments of inertia with

respect to the principal axes are called the principal moments of inertia and possess either maximum or minimum values.

INERTIAL ACTIVATOR. Activator, inertial.

INERTIAL FORCE. A reactive force that is equal in magnitude, and opposite in direction (or more strictly, in sense) to the force producing it. (See **Newton's Third Law of Motion**.)

INERTIAL FRAME OF REFERENCE. A regime in which a derivative of the first law of Newton is assumed to hold, i.e., a particle free from forces is unaccelerated. In a general sense it is used for any dynamic system which is not best defined with reference to the earth; an earth reference introduces complications, especially in dynamics problems, due to its motion and curvature. An inertial frame of reference is free from all space motion, and provides a space-fixed zone for the absolute measurement of the events of mechanics. For events of short duration and insignificant dimensions when compared to the size of the earth, a limited inertial frame can be assumed to exist on the earth, with small error. The conversion of a description of a motion from a space-fixed (inertial) system, to an earth-fixed system, requires calculation of accelerations caused by the relative motion between the two frames, and their application as corrections to the basic equations of motion. Since all observing instruments and measuring devices are attached to the earth, there is no means for experimental measurements in a true inertial frame of reference.

INERTIAL-GRAVITATIONAL GUIDANCE SYSTEM. Guidance system, inertial-gravitational.

INERTIAL GUIDANCE. Guidance, inertial.

INERTIAL NAVIGATION SYSTEM. Navigation system, inertial.

INERTIAL SYSTEM. A system which determines the displacement of its carrying vehicle from its starting point by measuring the accelerations of the vehicle relative to the earth.

INFINITE ASPECT RATIO (THEORY). The theoretical assumption that the aspect

ratio of an airfoil has a mathematically long span compared to the area of its surface. The concept is used to simplify aerodynamic relationships and exclude minor factors which have second or third order effects. The assumption of infinite aspect ratio allows the application of two-dimensional flow theories, and eliminates the wing tip disturbances from consideration.

INFINITESIMAL BODY. The concept used in **central force field theory**, denoting a body whose mass is negligible in comparison with the center mass, and which thus does not attract the center body by an amount within the accuracy limits of the discussion.

INFLIGHT CALIBRATION. A method of correcting telemetry channels for errors due to voltage and frequency drift occurring during the flight of a missile. (See also **Data reduction**, **linearization** and **telemetry**.)

INFLUENCE COEFFICIENTS. Constants of proportionality which permit determination of a given parameter at one point when certain related characteristics are known at another point.

INFLUENCE FUZE. A fuze using some property of the target other than actual impact for detonation, e.g., a proximity (radar-return) fuze.

INFLUENCE LINE. A graphical relationship which usually pertains to a particular section of a beam. It is a curve so drawn that its ordinate at any point represents the value of the reaction, vertical shear, bending moment or deflection produced at the particular section by a unit load applied at the point where the ordinate is measured. An influence line may be used to show the effect of load position on any quantity dependent thereon, such as the stress in a given truss member, the deflection of a truss, the twisting moment in a shaft, etc.

INFRARED ABSORPTION. The absorption of infrared radiation by crystals is due to the excitation of lattice vibrations in which ions of opposite charge move relative to one another.

INFRARED DETECTOR. A thermal device for observing and measuring infrared radiation, including instruments such as a **bolom-**

eter, **radio-micrometer**, **thermopile**, **photocell**, and **photographic plate**.

INFRARED RADIATION. The band of electromagnetic wavelengths lying between the extreme of the visible (circa 0.75 microns) and the shortest microwaves (circa 1000 microns). Because many molecular-energy levels correspond to radiation in this range, infrared absorption spectra are of great use in chemical analysis, particularly of organic compounds. Since all bodies (not at absolute zero) radiate in this range, infrared systems are of increasing importance to the military, since warm targets can be detected in the dark by their own radiation as distinguished from the necessity of illuminating a target to make it visible. Infrared radiation is sometimes incorrectly called "heat radiation" because warm bodies emit the radiation and bodies which absorb the radiation are warmed. However the radiation is not itself "heat."

The infrared region is sometimes subdivided as follows:

	Wavelength in Microns
Near infrared.....	Circa 0.75- 3.0
Middle infrared.....	3.0 -30.0
Far infrared.....	30.0 -circa 1000

INFRARED SPECTRUM. A portion of the electromagnetic spectrum in which the wavelength is between 7.5×10^{-5} and 0.1 cm. It falls between the visible light and the microwave regions of the spectrum.

INFRASONIC (SUBSONIC). Having a frequency below the audible range. Frequencies above the audible range are termed ultrasonic.

INHABITED MISSILE. A weapons system in which a human pilot has over-riding control over operations, but where take-off, target acquisition, engagement, and return to base are all accomplished automatically for the pilot. He takes over only if necessary and when landing.

INHABITED VEHICLE. A vehicle (e.g., an airplane or rocket) carrying a person or people, as distinguished from an uninhabited missile or projectile.

INHERENT STABILITY. Stability, inherent.

INHIBITOR. (1) In general, a fuel additive used to minimize an undesirable property.

(2) An inert material surrounding a solid-propellant rocket grain to limit burning except on desired surfaces.

INITIAL FAILURE. Failure modes.

INITIAL MASS. Specifically the mass of a rocket projectile at the beginning of its flight.

INITIAL OPERATIONAL CAPABILITY (IOC). A term used to describe, comprehensively, the initial adequacy of a weapon system to be used in the field operationally.

INITIATION. The application of a fuze signal to the first elements of an explosive train.

INJECTION PRESSURE. The pressure difference between the total pressure at the fuel outlet orifice, and the pressure in the combustion chamber.

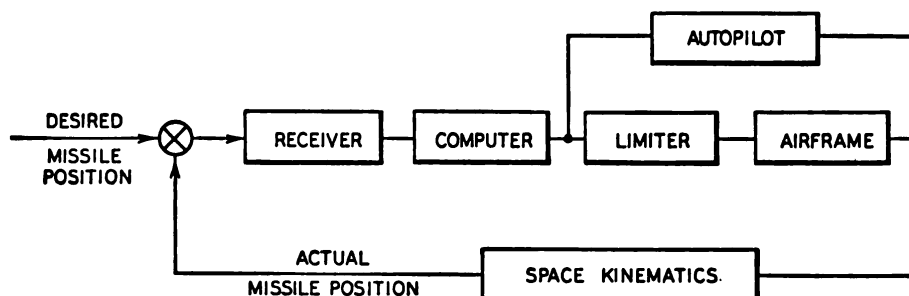
but are mixed as a result of the combustion chamber turbulence.

INJECTOR, SPRAY. A liquid rocket engine injector in which the oxidizer and fuel are mixed by intersection of spray patterns.

INNER BODY. Any closed body located in a ramjet, or other duct, around which the air taken into the diffuser or engine must flow.

INNER CONE. The cone-shaped component situated just behind the turbine wheel in an exhaust cone.

INNER LOOP. In guided missile control systems, the feedback loop consisting of the control system and missile aerodynamics as contrasted to the outer loop, which includes the external guidance system kinematics. (See Figure.)



Simplified block diagram of generalized guidance system.

INJECTOR. In liquid rocket engines, the device which functions to direct, mix and atomize the propellants to provide a proper mixture for combustion. Injectors range in complexity from a single pair of circular orifices to elaborate mixing units consisting of hundreds of carefully-designed impinging orifices of critical orientation and diameter, bored through a heavy steel plate, which forms the head of the combustion chamber. (See **injector, non-impinging**; **injector, impinging**; **injector, spray**.)

INJECTOR, IMPINGING. A liquid rocket engine injector in which the oxidizer and fuel are mixed by the intersection of jet-streams at a predetermined point.

INJECTOR, NON-IMPINGING. A liquid rocket engine injector in which the oxidizer and fuel do not impinge at a specific point

INSERTION GAIN, TRANSDUCER. The gain resulting from the insertion of a transducer in a transmission system, which is the ratio of the power delivered to that part of the system following the transducer, to the power delivered to that same part before insertion of the transducer. If the input and/or output power consists of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. This gain is usually expressed in decibels. The "insertion of a transducer" includes bridging of an impedance across the transmission system.

INSERTION LOSS, TRANSDUCER. The loss resulting from the insertion of a transducer in a transmission system, which is the ratio of the power delivered to that part of the system which will follow the transducer,

before insertion of the transducer, to the power delivered to that same part of the system after insertion of the transducer. This ratio is usually expressed in decibels. If the input power, or the output power, or both consist of more than one component, the particular components used must be specified.

INSPECTION. Examination of an item to determine compliance with established standards and/or specifications.

INSPECTION, PERIODIC. An inspection repeated either at regular intervals of calendar time or, in reference to certain equipment, after it has been used for a given number of hours.

INSPECTION, VISUAL. Inspection by the use of the eyes only; it does not include use of any measuring devices, tools, or equipment.

INSTALLATION. A separately located and defined area of real property in which an armed service exercises real property interest or has jurisdiction over real property. The term, real property, as used here, includes lands and interest therein, buildings and structures, utility systems, runways, and installed equipment. Installation is synonymous with Air Force Base, Naval Base, etc.

INSTALLATIONS CONCEPT. A broad over-all statement of the installations operation to be performed. It contains an outline of the objectives, assumptions, criteria, and capabilities needed in the preparation of the installations plan.

INSTALLATIONS PLAN. The projected method of obtaining the goals prescribed in the installations concept. The plan is developed from the guidance contained in the concept.

INSTALLED EQUIPMENT. Nonexpendable or expendable recoverable equipment permanently attached to or integrated into real property in such a manner that it cannot be removed without causing substantial physical damage or change to the real property.

INSTANTANEOUS IMPACT PREDICTION (IIP). The prediction of the anticipated impact point of a missile or reentry body by means of a ground-based computer using appropriate tracking data. Used for range safety.

INSTANTANEOUS SOUND PRESSURE. Sound (acoustomotive) pressure.

INSTRUCTION. Information which, when properly coded and introduced as a unit into a **digital computer**, causes it to perform one or more of its operations. An instruction commonly includes one or more **addresses**.

INSTRUMENT LANDING. A landing without visual reference to the ground, especially during its initial stages, made with the aid of aircraft instruments and ground-based electronic devices or communication systems.

INSTRUMENTAL COMETS. A class of space vehicles comprising **planetary probes** and **solar probes**. They are to be employed on one-way missions, at least in the foreseeable future. Therefore, no propellant weight has to be carried for the return flight. Liquid oxygen or fluorine and possible hydrogen can be used for departure without requiring provisions for storage of these materials over a period of months or years. As the comet probe escapes the earth's field along a hyperbolic path, the main propulsion system, including the tanks, can be separated. If provisions for later path corrections—by terrestrial command or otherwise—are desired, a second small propulsion system operating on less volatile propellants of good long-time storage characteristics can be used. The thrust-to-weight ratios involved in these maneuvers will be small and the required changes in flight path will be slight, so that super-impulse propellants are not required. Absence of food, water, air conditioning and many other biological and safety requirements yield an enormous weight saving for the instrumental comet, as compared to the interplanetary space ship.

INSTRUMENTAL VEHICLES FOR SPACE RESEARCH. Instrumental or automatic space vehicles are artificial, pilotless spacecraft which move outside the earth's atmosphere and operate either fully automatically or by command from the earth or another space vehicle (space relay). They may be designated from their principal flight characteristics as referred to earth, and so be said to consist of three major groups: (1) **Circumterrestrial satellites**, comprising terrestrial satellites, cislunar satellites and translunar satellites; (2) **Lunar probes**, comprising lunar

Collective Designation	Vehicle Type	Orbit	Orbital Specifications	Orbital Velocities (ft/sec)	Ideal Energy Velocity (ft/sec) ²	Ideal Velocity Changes Starting From Datum Orbit (ft/sec) ³	
Circumterrestrial satellites	terrestrial satellites		$\sim 300 \leq \gamma \leq 3444$ n.mi.	circle $24,896 \geq v_c \geq 18,355$	circle 26,978 – 31,792	0 – 6394	
			$1.087 \leq \frac{r}{r_0} \leq 2$	ellipse ($r_0/r_m \leq 2$) $v_p \leq 28,338$ $v_a \leq 15,405$	ellipse ($r_0/r_m \leq 2$) $\leq 30,184$	ellipse ($r_0/r_m \leq 2$) $\Delta v_{cp} \leq 3443$	
	cislunar satellites		circle: $\sim 2 \leq \frac{r}{r_m} \leq \sim 30$	$18,355 \geq v_c \geq 4739$	31,792 – 36,403	$6394 \leq \Sigma \Delta v \leq 3177$	
			ellipse: $\sim 2 \leq \frac{r}{r_m} \leq \sim 100$	$28,338 \leq v_p \leq 35,019$ $15,405 \geq v_a \geq 444$	30,184 – 36,528	$3443 \leq \Delta v_{cp} \leq 10,122$	
	translunar satellites		circle: $\sim 70 \leq \frac{r}{r_0} \leq \sim 10,000$	$\frac{r}{r_0}$ v_c 70: 3101 100: 2596 1000: 821 10,000: 260	36,579 – 36,709	$\frac{r}{r_0}$ $\Sigma \Delta v$ 70: 12,602 100: 12,338 1000: 11,076 10,000: 10,568	
Lunar probes	lunar satellites		altitude from lunar surface 500 n.miles	leaving datum orbit $v_p = 34,893$ lunar satellite orbit (circular) $v_c = 4457$	transfer ellipse $r_0/r_m = 60$ 36,408 capture moon 1878 total 38,286	leaving datum orbit $\Delta v_{cp} = 9998$ capture moon 1878 total 11,876	
	lunar landing vehicles		A: descent only B: return to D.O. A-B: lunar landing and return	—	A: 45,473 ⁽⁴⁾ B: 17,805 A-B:, 63,278	A: 19,063 ⁽⁵⁾ B: 17,805 A-B: 36,868	
Interplanetary probes	Instrumental comets	Martian probe		no Martian capture no recovery	leaving datum orbit 36,497	datum orbit 26,978 departure 11,601 total 38,579	11,601
		Venusian probe		no Venusian capture no recovery	leaving datum orbit 36,138	datum orbit 26,978 departure 11,242 total 38,220	11,242
		solar probe		perihelion slightly inside orbit no recovery	leaving datum orbit 44,501	datum orbit 26,978 departure 19,605 total 46,583	19,605
	Planetary satellites	Martian satellite		Martian altitude of 6000 n.mi. assumed	leaving datum orbit 36,497 Martian satellite orbit (circular) 6125	transfer orbit: 38,579 capture Mars: 6125 total 44,704	leaving datum orbit 11,601 capture Mars 6125 total 17,726
		Venusian satellites		Venusian altitude of 2000 n.mi. assumed	leaving datum orbit 36,183 Venusian satellite orbit (circular) 9190	transfer orbit: 38,220 capture Venus: 9190 total 47,410	leaving datum orbit 11,242 capture Venus 9190 total 20,432

- 1) For a discussion of the various assumptions in this table of text.
- 2) Energy velocity is the equivalent velocity of all kinetic and potential energy changes, beginning with the ascent from the earth's surface
- 3) Datum orbit: altitude $\gamma = 300$ n miles, corresponding circular velocity: $v_c = 24,896$ ft/sec
- 4) A-transfer orbit- 36,408, capture- 1878; landing- 7187; total= 45,473
B-lunar take-off- 5502; lunar escape- 2305; earth capture- 9998
A-B-total $\Sigma v = 63,278$
- 5) A-leaving datum orbit- 9998; lunar capture- 1878; lunar descent- 7187; total= 19,063
B-lunar take-off- 5502; lunar escape- 2305; earth capture- 9998; total= 17,805
A-B- 36,868

Survey of instrumental vehicles for space research.

satellites and lunar landing vehicles; and (3) **Hyperbolic probes** comprising instrumental comets (Martian probes, Venusian probes, solar probes) and circumplanetary satellites (Martian satellites and Venusian satellites).

For lunar probes, see **Thor Able** and **Pioneer**.

In their general characteristics, the instrumental vehicles for space research constitute transitional types between missiles and manned spacecraft. Since they occupy this important position, a tabular statement of the important stages of this development is given.

which is completely operable within the missile. *External instrumentation* refers to optical, radar, Doppler position finding equipment, and all others which operate independently of the missile itself.

INSTRUMENTATION CONSOLE. The console, housed in the control building, controls all ground instrumentation equipment, including the central timing system.

INSULATION. Material used to retard the flow of heat or electricity. Electrical insula-

TRANSITION FROM MISSILE TO SPACECRAFT

Dominant Characteristics

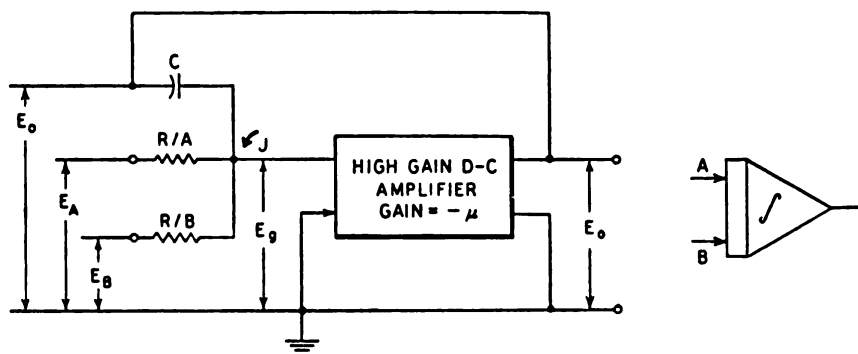
TERRESTRIAL CONDITIONS	EXTRATERRESTRIAL CONDITIONS
<i>Environmental</i>	
Surface (launching, storage)	Vacuum
Atmosphere (drag, thrust, re-entry)	Cosmic radiation
	Interplanetary dust
	Weightlessness
<i>Technical</i>	
High thrust-to-weight ratio	Low thrust-to-weight ratio
Low altitude expansion nozzles	High-altitude expansion nozzles
High structural loads	Applicability of propulsion systems requiring vacuum to operate
Aerodynamic heating	No shape requirements
Aerodynamic coefficients	Long-term equipment reliability
	Systematic utilization of solar power
<i>Flight Mechanical</i>	
Line of motion: trajectory	Line of motion: orbit
Effect of non-gravitational forces on flight path (accuracy, performance)	Effect of gravitational forces on orbit (perturbation)
Trajectory deflection (drag losses, g-losses)	Three-dimensional maneuvers
Performance parameters: Payload weight, range	Performance parameters: Payload weight, orbital energy
<i>Mission</i>	
Terrestrial targets	Space targets (3-dimensional distribution)
Impact point accuracy (CEP)	Orbital characteristics
Flight time	Intersection accuracy
	Flight time
<i>Operation</i>	
Surface-to-surface constraint of mission profile	Space launching
On-surface logistics	Earth-to-space logistics
Surface storage characteristics	Flight mechanical constraints on launching time (motion of launcher & target)
No flight mechanical constraints on launching time	Strong effect of flight direction on flight performance (inclination of transfer orbit to orbit of departure)
Slight effect of flight direction on flight performance (earth's rotation)	Space storage

INSTRUMENTATION. Devices used to gather quantitative data on a guided missile system or its components while these are operating or being tested. *Internal instrumentation* refers to telemetering recorders carried on board the missile, or any other devices

tion is grouped in classes for purposes of engineering design as follows: *Class "A" insulation*. (1) Cotton, silk, paper and similar organic materials impregnated with a dielectric. (2) Molded or laminated celluloses, phenolic resins and other resins. (3) Films

and sheets of cellulose acetate and other cellulose derivatives. (4) Varnishes and enamels applied to conductors. *Class "B" insulation.* Mica, asbestos, fiber glass, and similar inorganic materials built up with organic binding substances. *Class "C" insulation.* Mica, porcelain, glass, quartz, and similar inorganic materials. *Class "O" insulation.* Cotton, silk, paper, and similar organic materials not impregnated. *Class "H" insulation.* An impregnating varnish as used on motor windings.

tance-capacitance electric circuit (actually a low-pass filter). The resistor R changes the input voltage to a current proportional to the input voltage. As the capacitor C charges, the voltage across R changes from the input, and the current through R is not proportional to the input voltage. Thus the circuit is not a perfect integrator, but the output voltage is proportional to the integral of the current through R , and hence to the integral of the input voltage. A more sophisticated integrating circuit is shown in the figure.



Integrating amplifier circuit and symbol.

INTEGRATING ACCELEROMETER. Accelerometer, integrating.

INTEGRATING CIRCUIT. A circuit whose output wave form is the time integral of one or more input wave forms.

INTEGRATING GYROSCOPE. HIG (Gyro); gyroscope, integrating.

INTEGRATOR. In guided missile computers, a device which performs the mathematical operation of integration, usually by mechanical or electrical means. Most commonly, the input is acceleration information, and the output is velocity (single integration) or position (double integration) information. The oldest integrator (which is still used in missile systems) is the ball-and-disc integrator, which consists of a flat, circular, rotating plate. A ball riding in a cage rests on this plate. A pinion gear system permits the ball carriage to be pushed in or out, so that the ball can move from the center of the rotating disc to its rim. The angular velocity of the ball represents the integrated output of the speed of rotation of the disc and the distance of the ball cage from the center of the disc. Another integrator is the simple resis-

INTELLIGENCE BANDWIDTH. The sum of the audio (or video) frequency bandwidths of the one or more channels.

INTELLIGIBILITY, DISCRETE WORD. The per cent intelligibility obtained when the speech units considered are words (usually presented so as to minimize the contextual relation between them).

INTENSITY, ELECTRIC. Field strength; and field, electric.

INTERCEPTOR. (1) An aircraft or missile used for intercepting, e.g., a fast, well-armed airplane for intercepting and destroying enemy bombers. (2) A lateral-control device placed just behind a wing slot to spoil the effect of the slot at high angles of attack.

INTERCEPTOR LEAD-ANGLE. The angle between the flight path of an interceptor on a collision course with a target and the interconnecting line of sight.

INTERCEPTOR MISSILE. A guided missile, especially one launched from the ground, intended to intercept and destroy aircraft or other missiles. The Bomarc (IM-99) is an example.

INTERCONTINENTAL. Capable of traveling nonstop between continents.

INTERCONTINENTAL BALLISTIC MISSILE. The 5,000-mile range ballistic missile. In the United States this development was assigned to the U.S. Air Force. In 1953 the Air Force began a study project called "Atlas" through a contract with Convair. In 1955 when it became apparent that the U.S.S.R. was well advanced in this field and that a thermonuclear warhead was feasible, the ICBM program was expanded under the technical direction of the Ramo-Wooldridge Corporation as a contractor to the Air Force. At this time two ICBM's were ordered: Atlas, WS 107A-1 and Titan, WS 107A-2. The Air Force also created a new organization, the Western Development Division (later the Ballistic Missile Division) of the Air Research and Development Command, under Major General B. A. Schriever, USAF. The first ICBM, Atlas, was fired unsuccessfully in June of 1957. (See *Atlas* and *Titan*, M-104 and T-3.) Because of geodetic uncertainties even an astronomically-precise rocket fired from one continent to another will be in error a matter of several kilometers merely because of the absence of any precise knowledge of where a given target really is with respect to the launching site. Even assuming precise survey data, it can be seen by simple arithmetic that for a vehicle to fall within 10 miles of a given point when fired from a distance of 5,000 miles, it must be guided with an accuracy of 1 part in 500 or 0.2% precision. This precision assumes a high **reliability**, which is another problem yet more difficult.

INTERDICTION FIRE. Artillery fire so conducted as to interrupt periodically (or erratically), or to make temporarily unusable a communications route.

INTERDIGITATED. Spaced or aligned alternately, e.g., wings and tail surfaces which are not in the same plane in order to reduce aerodynamic interferences.

INTERFACE. (1) The boundary, electrical and/or mechanical, existing between two systems or components. Characteristics are usually specified by installation, interface, or coordination drawings and coordinated tooling. (2) The boundary between two media,

especially as transited by a propagated wave.

INTERFERENCE. (1) The variation of wave amplitude with distance or time, caused by the superposition of two or more waves. As most commonly used, the term refers to the interference of waves of the same or nearly the same frequency. Wave interference is characterized by the phenomenon of the occurrence of local maxima and minima of **wave amplitude**, which cannot be described by the ray approximation to solutions of the wave equation. In terms of the Huygens approximation, interference can occur whenever wave disturbance can be propagated from a source to a region of space by two or more paths of different length. There is (destructive) interference if the phases and amplitudes of the disturbances arriving by the various routes are such as to reduce the square of the resultant amplitude below the sum of the squares of the amplitudes of the components. Two or more sources may only be used if there is a fixed phase-relation between them.

(2) Sound interference results when the waves concerned are **sound waves**. (3) Optical interference occurs with light waves. Thus, a beam of radiation may be separated into two parts, follow different paths and then brought back to form a single beam. Unless the two paths are of identical optical length, the two beams may not be in phase, and can destructively interfere at some points (dark) and constructively interfere at other points (bright). From the principle of conservation of energy, it is known that there is not a loss in energy due to interference. The energy missing at dark points will be found in the bright points. Interference patterns are commonly light and dark bands, all of equal width. Light beams which can cause interference patterns are called "coherent," while beams which cannot cause interference patterns are "incoherent." (4) In a signal transmission system, interference is either extraneous power which tends to interfere with the reception of the desired signals, or the disturbance of signals which results. (5) In aerodynamics, that which occurs when surfaces or bodies influence the flow around others, as, the *interference* between the two wings of a biplane, or between two fins of a rocket.

INTERFERENCE, ADJACENT-CHANNEL. **Interference** in which the extraneous power

originates from a signal of assigned (authorized) type in an adjacent channel.

INTERFERENCE, CO-CHANNEL. Interference between two signals of the same type in the same radio channel.

INTERFERENCE CONTROL. On guided missile ranges, the processes of monitoring the radio frequency spectrum to detect conflicting signals. The process includes action taken to reduce the interference through the suppression of signals likely to interfere, the avoidance of conflict by the assignment of discrete frequencies, the control of operating times by centralized scheduling, and the use of frequency stabilizing techniques (e.g., **crystal control**) where possible. Interference control monitoring is done from both ground and air stations. Equipment for this purpose is used in seeking, recording, and analyzing the interfering signal. The analysis can reveal the frequency, signal strength and electrical characteristics of signal (e.g., **pulse width, pulse repetition rate, band width, and modulation system**).

INTERFEROMETER. An apparatus used to produce and show interference between two or more wave trains from the same area, and also to compare wave lengths with observable displacements of reflectors, or other parts, by means of interference fringes. (See figure.)

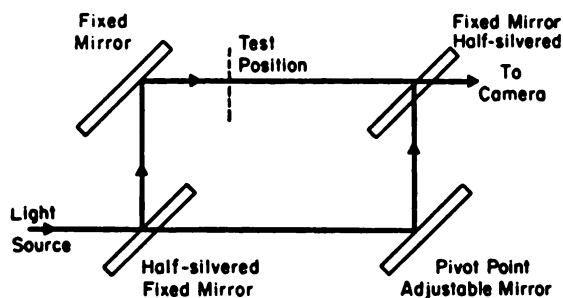


Diagram of interferometer.

An interferometer is frequently used to obtain quantitative information on flow around bodies in wind tunnels. The instrument there measures the interference resulting from travel through an undisturbed portion of the wind tunnel airstream as compared to that through a shock wave.

INTERFEROMETER HOMING. Homing, interferometer.

INTERGALACTIC SPACE. Space, intergalactic.

INTERIM. A military research and development term referring to an item of known inferiority which is being used temporarily because of budgetary limitations, shortage of materials, lack of time, and similar reasons.

INTERIOR BALLISTICS. Ballistics.

INTERLOCK. A device used to govern a sequence of operations to prevent injury to personnel or damage to equipment.

INTERMEDIATE FOCAL LENGTH TRACKING TELESCOPE (IFLTT). 35 mm and 75 mm cameras with 40" and 80" lenses for high speed tracking of missiles during early portions of the trajectory.

INTERMEDIATE FREQUENCY. A frequency between two working frequencies. In the superheterodyne receiver the intermediate frequency (IF), lies between the incoming radio frequency signal and the output audio signal. The incoming signal is of too high a frequency for the most efficient amplification and detection of the intelligence and the IF is a technique by which the incoming signal can be converted to a single-valued lower frequency containing the same intelligence. This allows circuitry in the receiver to be designed to handle the one single IF to best advantage rather than requiring that a large range of frequencies be handled. Home receivers normally use 456 kc/s and receivers of special applications use other IF's depending upon the frequency band being worked. (See **superheterodyne receiver**.)

INTERMEDIATE RANGE BALLISTIC MISSILE (IRBM). Missile, intermediate range ballistic.

INTERMETALLICS. Compounds of metals with other metals or with non-metals with a wide variety of uses. Some are semiconductors, some are a-c rectifiers, and some have still other properties. Some intermetallics are: titanium tetraboride (a refractory intermetallic), cerium monosulfide (a rocket fuel), cadmium sulfide (sensitive to light and used in the solar battery), silver iodide (solid electrolyte for small batteries), and others such as gallium arsenide, indium phosphide and indium antimonide.

INTERMITTENT JET. Pulsejet.

INTERMODULATION. The modulation of the components of a complex wave by each other, as a result of which waves are produced which have frequencies equal to the sums and differences of integral multiples of the components of the original complex wave.

INTERNAL EFFICIENCY. The efficiency with which a reaction engine, such as a rocket, converts the available thermal energy of its combustion gases into kinetic energy in the exhaust jet, expressed as a ratio.

INTERNAL ENERGY. Energy, internal.

INTERNAL INSTRUMENTATION. Data collection equipment carried within a missile, such as telemetering equipment, television cameras, moving picture cameras and the like. (See also **external instrumentation** and **instrumentation**.)

INTERNAL STAR-SHAPED GRAIN. Star grain.

INTERNATIONAL GEOPHYSICAL YEAR. By international agreement between scientific organizations successive periods approximating eighteen months have been selected for intensified study of the **geoid** and its associated phenomena. Each such period is termed a (International) Geophysical Year.

INTERPLANETARY. Between planets, as in interplanetary navigation; of or pertaining to the region between planets, as in interplanetary research; designed for travel in this region, as in interplanetary rocket.

INTERPLANETARY DUST. Particles of material in interplanetary space which is observed by its opacity or diffraction of light or other radiation.

INTERPLANETARY SPACE. Space, interplanetary.

INTERROGATION. The transmission of a signal designed to trigger an electronic apparatus, such as radar beacon **transponder**. If the beacon is compatible with the radar beam, it emits its response.

INTERROGATOR-RESPONDER. An electronic device combining a **transmitter** for sending pulses interrogating a **transponder**,

and a receiver for receiving and displaying the answering pulses of the transponder.

INTERRUPTED CONTINUOUS WAVE (ICW). Continuous wave, interrupted.

INTERSTELLAR. Between the stars, or pertaining to the space between them.

INTERSTELLAR SPACE. Space, interstellar.

INTERVALOMETER. Any device that may be set so as to accomplish automatically a series of like actions, such as the taking of aerial photographs, at a constant predetermined interval.

INTRA-PLANETARY SPACE. Space, intra-planetary.

INVERSE FEEDBACK. Feedback, inverse.

INVERSE FEEDBACK FILTER. Filter, inverse feedback.

INVERSE MERCATOR PROJECTION. A special case of the transverse **Mercator Projection**, being that projection which results if the cylinder on which the earth's surface is projected is placed tangent to the earth at a meridian.

INVERSION. (1) In the normal condition of the earth's **atmosphere**, the temperature decreases with altitude. When temperature increases with altitude, normal conditions are inverted, and the condition is said to be an inversion. Inversions in the troposphere are usually restricted to shallow layers of air which most frequently occur in the lower 5000 ft above the surface. In low latitudes the stratosphere has a slight inversion more or less permanently. (2) In optics, the transformation of an optically-active substance into one having the opposite rotatory effect, without essential change of chemical composition. (3) In communications, a form of speech-scrambling which essentially inverts the original frequency spectrum of the signal. This may be accomplished by modulating the signal with a relatively low-frequency carrier, and then discarding the carrier and upper sideband.

INVERTER. In electricity, a device for changing d-c into a-c. Inverters are frequently used in missiles to convert storage battery d-c to a-c.

IOC. Initial operational capability.

IODINE. Halogen element. Symbol I. Atomic Number 53.

ION. An atom or molecularly-bound group of atoms which has gained or lost one or more electrons, and which has thus a negative or positive electric charge; sometimes a free electron or other charged subatomic particle. Ions may be produced in gases by the action of radiation of sufficient energy; ionic solids are built up of ions bound together by their electrostatic forces, and when dissolved in a polar liquid, such as water, the solid dissociates into its ions, which have an independent existence.

ION BEAM. A beam of charged particles other than electrons, all moving with essentially the same speed in a nearly common direction. Ion beams are produced by the application of electrical and magnetic forces to ordinary ions and other particles, as in the production of a beam of α -particles by applying potentials in the millions of volts to the particles from a helium discharge tube; or as in the acceleration of ionic particles to great velocities by a particle accelerator.

ION ENGINE. A reaction engine in which thrust is obtained from a stream of high-momentum ions, as obtained from a process such as molecular dissociation, nuclear fission, nuclear fusion, etc.

ION PROPULSION. A means of obtaining propulsion for space ships by expelling ions and electrons from a combustion chamber. The recombination aft of the chamber prevents space charge effects which would counteract the thrust. The scheme is intended for propulsion in gravitationless space where a microforce thrust of this sort might be operated over a long period of time to yield extremely high vehicular velocities. Dr. Ernst Stuhlinger of the Army Ballistic Missile Agency refined Professor Oberth's ideas into a theoretically practical machine using cesium and rubidium as "fuels." Originally, Professor Oberth neglected to provide for neutralization of the expelled ions and his theoretical motor would eventually have stopped from the collection of a strongly charged ion cloud behind the outlet. Dr. Stuhlinger's apparatus effectively neutralizes the ions. Such a motor

has been built by the Rocketdyne Division of North American Aviation, utilizing cesium ions. It has high fuel efficiency and long fuel life, but low thrust, so its usefulness is limited to outer space, on rockets hoisted there by other engines.

IONIC CHARGE. Either the total charge carried by an ion, or the charge carried by an ion which has unit charge. Since ions owe their charges to gain or loss of electrons, unit charge is the charge on an **electron**, and all ionic charges are either equal in magnitude to this value, or integral multiples of it.

IONIC EQUILIBRIUM. In any **ionization**, at any particular temperature and pressure, the conditions at which the rate of **dissociation** of unionized molecules, or other particles to form ions, is equal to the rate of combination of the ions to form the unionized molecules, or other particles so that activities and concentrations remain constant as long as the conditions are unchanged.

IONIC INTERFERENCE. Ionization.

IONIZATION. A process which results in the formation of **ions**; usually from neutral atoms or molecules by charging them positively or negatively. Ionization processes of solvents and of gases are widespread, and have great technological and scientific importance.

In high energy rocket propulsion, hot exhaust gases cause ionization of the exhaust products and the air (if any) into which they are ejected. This ionization interferes with the passage of radio frequency energy through the ionized region. This can attenuate guidance signals from the ground, interfere with telemetry signals from the missile, or block radar beacon signals. Care is exercised in the materials used in rocket fuels in order to avoid the ionization problem as much as possible.

A rocket motor generates voltages on the order of 20,000 volts because of its high energy. All possible ion-forming materials must be removed from the combustion fuels to avoid ionization under such conditions.

IONIZE. The action of producing **ionization**.

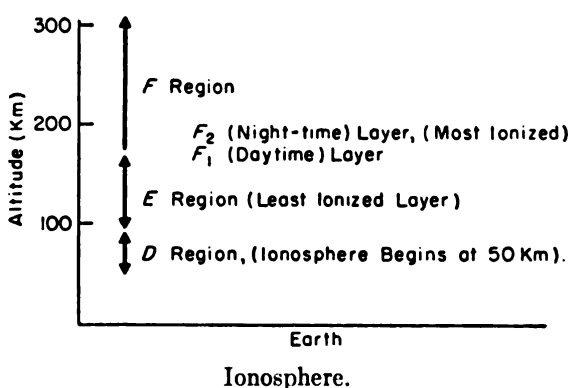
IONOGEN. A substance which dissolved in a solution produces an electrolyte or fluid capable of conducting a current.

IONOPAUSE. The top of the **ionosphere**. The ionopause marks the boundary between the ionosphere and the exosphere.

IONOSPHERE. (Heaviside layer; Kennelly-Heaviside layer; E layer.) That part of the atmosphere extending from 30 miles to 250 miles altitude. Regions of ionization (approximate maxima):

- D Layer—35 to 40 miles
- E Layer—70 to 80 miles
- F₁ Layer—135 to 145 miles
- F₂ Layer—190 to 230 miles

The ionosphere consists of layers of highly ionized air capable of bending or reflecting certain radio waves back to the earth. Ionization results principally from solar radiation. Some seasonal and day-to-night variation is expected. (See figure.)



Ir. Iridium.

I²R LOSS. Power loss in transformers, generators, connecting wires and other parts of a circuit due to current flow through the resistance of the conductors. It is also termed "copper loss."

IRBM. Missile, intermediate range ballistic.

IRE. Institute of Radio Engineers.

IRIDIUM. Metallic element. Symbol Ir. Atomic Number 77.

IRIG. Inter-range instrumentation graph.

IRIS. A solid-propellant test rocket designed for the U.S. Navy for high altitude research during the International Geophysical Year (1957-1958). Its design performance predicted 200 miles altitude with a 100 pound payload. It was to be 13 feet long and 12

inches in diameter, and it was developed by the Atlantic Research Corporation. Its specifications called for a type of rocket which could be immediately launched after long periods in a "ready" condition, with a high degree of reliability of success. It was to be used for ionosphere research, as well as for investigation of cosmic radiation, ozone distribution, magnetic fields and upper atmosphere spectra.

IRIS-TYPE NOZZLE. A jet exhaust nozzle having a circular exit orifice of variable diameter.

IRON. Metallic element. Symbol Fe. Atomic Number 26.

IRON LOSSES. The **hysteresis** and **eddy current** losses in iron cores of electrical devices. (Compare **copper losses**.)

IRON VANE MOVEMENT. An electric meter movement in which two iron vanes are anchored at one edge, and then extend outward at a small angle, like a partly-opened hinge. A coil surrounding these vanes is so arranged that it can accept a current from outside, which causes the formation of an electric field. Since the magnetic field causes the two plates to become charged in the same polarity, they tend to repel each other, and the force of repulsion is utilized to move a pointer.

IRREGULAR VARIABLES. There are many **variable stars** which vary in brightness in such non-systematic manner as to be best designated as irregular variables. In some cases their manner of variation and spectral class is so similar to that of the long period variables that they are classed as members of this class of stars by some authorities. Notable among stars of this type are the bright stars α Orionis and α Herculis, both of which are **giant red stars**.

There are certain groups of irregular variables which have enough characteristics in common that they may be considered as groups. Such groups are usually designated by some typical star of the group. The RV Tauri group resemble to some extent the **Cepheids**, although their period, of the order of magnitude of 75 days, is far too long to permit their inclusion in the true Cepheid class. These stars are of G and K spec-

tral classes and their light curves are characterized by shallow minima coming between two deep ones. A few stars of the R Coronae Borealis type remain, often for several years, practically constant in brightness and then drop suddenly one or two magnitudes, returning to normal brightness after a few oscillations.

IRREVERSIBLE PROCESS. A process occurring in a system such that, in order to reverse the direction of the process, a finite change in the parameters of the system must be made, e.g., the compression or expansion of a gas in a cylinder by means of a piston, when friction is present between piston and cylinder.

IRT. Interrogator-Response-Transponder.

ISENTROPIC. Without change in **entropy**, e.g., a reversible adiabatic process is isentropic. All adiabatic processes are not isentropic, but only those which are reversible. Moreover, to be isentropic a hydrodynamic process must be friction-free. A process in which **shock waves** occur is not isentropic, and although this criterion is not sufficient for isentropy, it is used in aerodynamic studies to distinguish shock wave situations.

ISENTROPIC FLOW THROUGH A CONVERGING NOZZLE. A constant entropy thermodynamic process which is representative of the gas flow in a De Laval nozzle.

ISOBAR. (1) A line on a chart or diagram connecting points having the same barometric (or other) pressure. (2) A curve of constant acceleration loading of a pursuing aircraft flying a true pursuit course.

ISOCHRONES. Lines joining points at the same time, or having the same time values.

ISOCLINIC LINES. Lines connecting points bearing equal magnetic dip angles. Isoclinic lines are the counterpart of latitude lines in the geographical system and are rightly paralleled to the equator. The line connecting points having a zero vertical component (e.g., zero dip angle) is the magnetic equator.

ISODYNAMIC LINE. A line connecting places on charts of the earth's surface which have the same equal horizontal magnetic intensity. (See **magnetic field**.)

ISODROMIC. To fly the same course, as for example a beam-rider missile would be isodromic with respect to the beam. An isodrome is a missile which flies the same course as some other vehicle.

ISODYNAMIC LINES. Lines having equal magnetic intensity in the horizontal plane.

ISOELASTIC. Experiencing a strain which is proportional to the stress. This property is important in gimbal-mounted **gyroscopes** where a missile acceleration may produce distortions and unwanted precessions unless the gimbals and gyroscopes are isoelastic.

ISOGONIC LINES. A line on charts of the earth's surface connecting points having equal magnetic declination. Isogonic lines are the counterpart of longitudinal lines in the geographical system. The two lines along which the magnetic declination is zero are termed agonic lines.

ISOGRAM. (1) A line on a map or chart connecting points of equal value of some meteorological or climatological phenomenon. (2) The map or chart showing such lines.

ISOGRID. A line on charts of the earth's surface which joins points of equal magnetic variation from grid north.

ICOLINE. An **isogram** or **isopleth**.

ISOLUX. A curve or surface of equal light intensity.

ISOMAGNETIC. Lines connecting points at which some property of the earth's magnetic field (such as the magnitude, the vertical component, or the horizontal component) remains constant. Isomagnetic lines may indicate local magnetic anomalies such as caused by magnetic ore bodies, magnetic minerals in sediments, or the vertical rather than the horizontal deviation of the compass or magnetic needle.

ISOMER. (1) One of two or more substances which have the same elementary composition, but differ in structure, and hence in properties. (2) One of two or more nuclides which have the same mass number and atomic number, but differ in energetics and behavior.

ISOMER, NUCLEAR. One of two or more nuclides having the same **atomic number** and

the same **mass number**, but existing for measurable time intervals in different states. One state, that of lowest energy, is the ground state; and all those of higher energy are metastable states. Metastable isomers are denoted by adding the letter m to the mass number where it appears in the symbol for the nuclide, as $\text{Br}^{80\text{m}}$.

ISOPLETH. (1) An isogram showing the frequency of occurrence of a meteorological phenomenon in relation to two variables. (2) In less exact usage, an isogram. (3) A **nomograph**.

ISOPROPYL ALCOHOL. An organic compound having the formula: $\text{C}_3\text{H}_7\text{OH}$. It has a boiling point of 180°F , freezing point of -128°F , and a specific gravity of 0.7898.

ISOSTASY. A condition of approximate equilibrium such that the gravitational effect of masses extending above the **geoid** is approximately counterbalanced by a deficiency of density in the material beneath those masses.

ISOTHERM(S). (1) Lines joining points of equal temperature. Isotherms can be drawn for any surface or cross-section. (2) More generally stated, a relationship, or its analytical or graphical expression, for which the temperature is constant.

ISOTHERMAL. (1) Of constant temperature. Isothermal processes are those conducted without temperature change. (2) A line or curve expressing a relationship between variables such as pressure and volume, for all values of which the temperature remains constant. (3) A line joining points at the same temperature.

ISOTHERMAL REGION. The stratosphere considered as a region of uniform temperature. (See **atmosphere**).

ISOLATION NETWORK. A network inserted in a circuit or transmission line to prevent interaction between circuits on each side of the insertion point. Often a tube is used for this purpose.

ISOLATOR (SHOCK OR VIBRATION). Any material or structure which tends to diminish the effect of shock or vibration.

ISOLATOR EFFICIENCY. In an elastic system, the ratio of the energy absorbed by an **isolator** at a particular load and deflection (or stress and strain) to the product of the particular load and the deflection (or stress times strain).

ISOTOPE. One or two or more nuclides having the same **atomic number**, hence constituting the same element, but differing in **mass number**. In addition to this fundamental meaning of the term isotope, it is used for certain specialized meanings. One of these is as a synonym for isotopic tracer, a radio-nuclide used as a tracer for a substance with which it is isotopic. Another is as a synonym for a preparation of an element with a special isotopic composition (allobar) as an article of commerce, which may also find use as an isotopic tracer.

ISOTROPIC. In physics, having the same properties in all directions. In electronics, the term is used especially to describe omnidirectional antennas.

ISOTROPIC RADIATOR. A theoretical and hypothetical antenna that radiates or receives equally well in all directions. It is used as a reference to judge the directional characteristics of actual antennas.

ISOTROPIC WARHEAD. Warhead, isotropic.

ITERATION. In automatic computation, a process of solution wherein the critical manipulation is repeated until a solution is obtained to the desired accuracy. For example, multiplication can be accomplished by the process of iterative addition. That is, 10×45 can be determined by adding 45 to itself 10 times. In more complex manipulations, iterative process solutions are achieved by introducing approximate values of solutions and checking them successively, repeating the process until the desired accuracy in the result is reached by the series of converging trial solutions. By this process problems in higher mathematics are solved by successive repetitions of simple operations of addition and subtraction. The iterative process is time-consuming and seldom employed in **computers** designed for missile-borne use.

J

J. (1) Joule, (*J*). (2) Joule mechanical or electrical equivalent of heat, (*J*). (3) Radiant intensity (*J*), spectral radiant intensity (*Jλ*). (4) Heat transfer factor (*J*). (5) Gram-equivalent weight (*J*). (6) Action variable (*J*). (7) Electric current density (*J*). (8) Imaginary unit, $\sqrt{-1}$, in electric circuits (*j*). (9) Polar moment of inertia (*J*). (10) Unit vector in *Y*-direction (*j*). (11) Channel area ratio (*J*). (12) Ratio of nozzle throat area to area of charge port (*j*).

JACK. In electrical equipment, a type of connector permitting a rapid connection and disconnection of two components. Jacks are used with microphones, earphones, loudspeakers, and in patch panels where rapid changes are likely to be necessary. A *test jack* is one so placed in a circuit as to permit rapid checks of some electrical quantity if the test instrument is plugged into it. A jack is the female portion of the connection and appears on a panel as a hole to accept the plug. The jack has three contacting parts: tip spring, ring spring, and the sleeve, all of which make separate contacts on the plug.

JACKFIELD. A field of jacks.

JAMMER. An electronic device for jamming.

JAMMER, AUTOMATIC SEARCH. An intercept receiver and jamming transmitting system that automatically searches for and jams enemy signals of specific radiation characteristics.

JAMMER, REPEATER. A repeater jammer serves to confuse or deceive the enemy by causing his equipment to present false information; this is accomplished by a system that intercepts and reradiates a signal on the frequency of the enemy equipment, the reradiated signal being so modified as to cause the enemy equipment to present erroneous data on azimuth, range number of targets, etc.

JAMMING. A countermeasure technique in which an attempt is made to block a communication or control channel to abort an enemy mission.

JAMMING, ACCIDENTAL. Jamming due to transmission by friendly equipment.

JAMMING, ACTIVE. The intentional radiation or reradiation of electromagnetic energy with the object of impairing the use of a specific band of frequencies.

JAMMING, BARRAGE. The simultaneous jamming of a number of adjacent channels or frequencies.

JAMMING, OFF-TARGET. The employment of a jammer at a point removed from the main units of the force, this being done to defeat the enemy's use of our jamming signals to his advantage.

JAMMING, PASSIVE. The utilization of confusion reflectors to return spurious and confusing signals to the transmitting radar set.

JAMMING, SPOT. The jamming of a specific channel or frequency.

J-ANTENNA. Antenna, J.

JATO (Jet Assisted Take-Off). (1) A take-off utilizing an auxiliary jet-producing unit or units, usually rockets, for additional thrust. Hence, JATO bottle, Jato unit, etc., a rocket or unit so used. Where rockets are the auxiliary units, "RATO" is the more specific term. (2) A JATO bottle or unit; the complete auxiliary power system used for assisted take-off or to launch a guided missile.

JATO CANT POINT. The intersection of the jato chamber axis and nozzle centerlines.

JB-1. A U. S. Army Air Corps, jet-powered guided missile developed during World War II. It was basically a wing with a very short thick body (wing span was 30 feet) and was powered with two small jet engines.

JB-1A, JB-2. The U.S. Army Air Corps adaptation of the German V-1 missile. Engineers at Wright Field obtained a captured V-1 late in the war. Copies of the V-1 were made in this country in approximately 2 months time. The Ford Motor Company manufactured the motor and Willys-Overland manufactured the airframe. VE-Day came before the Air Corps was able to fire any of these back at the Germans. JB-2 was designed to be launched in the air from B-17's and B-29's. The U.S. Navy adapted the JB-1 to launching from submarines, thereby gaining invaluable background for the later **Regulus** and **Polaris**.

JB-10. Another U.S. Army Air Corps missile similar to the **JB-1**. It was merely a stubby barrel fuselage with a very long wing. It carried 2 tons of explosive in special compartments in the wing on each side of the fuselage. The missile was never used tactically.

JCS. Joint Chiefs of Staff.

JERK. In kinematics, the third derivative of displacement; rate of change of acceleration. Jerk is useful in defining the nature of shock loads.

JET. (1) A strong, well defined stream of fluid either issuing from an orifice or nozzle or moving in a contracted duct, such as the jet of combustion gases issuing from a reaction engine, or the jet in the test section of a wind tunnel. (See **free jet**.) (2) A tube, nozzle, or the like through which fluid passes, or from which it issues, in a jet, such as a jet in a carburetor. (See **pressure jet**.) (3) A jet engine, as, an airplane with jets slung in pods. (4) A jet airplane, as, the long runways needed for jets.

JET DAMPING. A decrease in the thrust value of a rocket motor because of a non-linearity of the flow of the exhaust gases due to a yawing of the vehicle. Yawing in this instance refers to the general case, which includes pitching. Any yawing motion of the rocket alters the gas stream. The thrust lost in the longitudinal direction is expended by the motor in reducing the rate of yaw, hence the damping connotation.

JET ENGINE. (1) Broadly, any engine that ejects a jet or stream of gas or fluid, obtaining all or most of its thrust by reaction to the

ejection. *Rare.* (See **reaction engine** and **propulsion**.) (2) Specifically an aircraft engine that derives all or most of its thrust by reaction to its ejection of combustion products in a jet and that obtains oxygen from the atmosphere for the combustion of its fuel—distinguished in this sense from a rocket engine. A jet engine of this kind may have a compressor, commonly turbine-driven, to take in and compress air (**turbojet**), or it may be compressorless, taking in and compressing air by other means (**pulsejet**, **ramjet**). Two general types are of major importance: (a) **Thermal Engines**, **ramjet**, **pulsejet**, **turbojet**. (b) **Rocket Engines**, liquid, solid.

JET HORSEPOWER. The power of the exhaust jet equal to the product of thrust and effective jet velocity.

Thrust (Jet) Horsepower

$$= \frac{\text{Thrust (lb)} \times \text{Speed (fps)}}{550}$$

$$= \frac{\text{Thrust (lb)} \times \text{Speed (mph)}}{375}$$

JET NOZZLE. A nozzle producing a jet of liquid or gas; an exhaust nozzle for the escape of gases from a jet engine or rocket.

JET PROPULSION. Propulsion, jet.

JET PROPULSION LABORATORY. A laboratory at the California Institute of Technology.

JET STREAM. (1) In meteorology, two circumpolar air currents moving in a highly-irregular, periodically-variable, east-to-west direction. Their general location is about 35,000-55,000 ft above the earth's surface, and to middle-to-northern and middle-to-southern latitudes; thus the northern hemisphere jet stream passes over the United States and the Mediterranean, with loops much farther north. The velocity varies from 100 to 500 miles per hour. (2) The stream of exhaust gas or liquid expelled from any reaction device, especially the combustion products expelled from a jet engine, rocket engine or rocket motor.

JET THRUST. (1) The **thrust**, measured in pounds, developed by a **jet engine**, **rocket engine**, or the like, in reaction to its jet stream. (2) The thrust of a jet engine.

JET VANE. A vane, either fixed or movable, used in a jet stream, e.g., in the jet stream of a rocket, for purposes of stability or control under conditions where air vanes are ineffective. (Cf. **air vane**.)

JET VANE CONTROLLED MISSILE. A missile which is controlled by special vanes placed in the exhaust nozzle of the sustaining rocket, or by some special jets acting normal to the missile centerline at a distance from the center of gravity to produce the necessary control moments.

JET VANE STABILIZATION. A means of controlling a missile by deflecting vanes in the exhaust stream of a (usually) rocket. Attitude stabilization only may be the objective (e.g., boost phase stabilization) or guidance and/or roll control may be obtained.

JET VELOCITY. The velocity of a jet stream, usually measured with respect to surrounding air.

JETAVATOR. A controllable surface which normally forms an extension of the exit nozzle of a rocket. It may encompass all or a portion of the periphery. When actuated the jetavator is rotated into the jet stream, partially deflecting it and producing a desired control moment.

JETEVON. A movable surface within or beside a jet exhaust for the purpose of attitude control by thrust deflection. The technique is the same as for **jet vanes** in a rocket motor, but jetecons are applied to aerodynamic-type missiles where the thrust deflection is for the purpose of aiding or replacing aileron and elevator moments during early take-off of a horizontally-launched missile.

JETTISON DEVICE. (1) A mechanism for jettisoning a missile from a ship or launcher. (2) A mechanism for jettisoning a section of a missile in flight, e.g., at staging of a ballistic missile.

JETTISON WEIGHT. The weight of equipment and parts dropped at staging of a ballistic missile; the weight of a booster.

JINDIVIK. An Australian target drone developed in 1951. It was reported to be 22 feet long, with 19½ feet wing span propelled by an Armstrong-Siddeley Adder or later by a Viper

turbojet. The configuration was a low-wing monoplane similar to the German V-1. Take-off was by jettisonable trolley from a regular airfield. Radio command guidance was used.

JITTER. A vibratory motion imparted either intentionally or unavoidably to mechanisms operating under **servo-control**. Intentional jitter is introduced to prevent sticking of valves, to direct radar antennas onto targets by means of error detections incident to their jittering motion, or for other mechanical or electrical reasons. Unintentional jitter can occur in servo connections because of a too "tight" control, i.e., tuning for too fast a response in following signals. (See also **beam jitter**.)

JLC. Joint Logistics Committee.

JOC. Joint Operations Center.

JOHNSON NOISE. The noise generated by any resistor at a temperature above absolute zero. It is proportioned to the absolute temperature and the bandwidth under consideration. The magnitude of Johnson Noise is given by: $N = KTB$ where N is the noise power in watts, K is the Boltzmann's constant, T is the absolute temperature in degrees Kelvin, B is the bandwidth in cycles per second.

JOLT AND JUMBLE TESTS. Environmental tests used to evaluate equipment for adequacy for handling and shipment.

JOULE. A unit of energy or work in the MKS system of **units**, abbreviation *J*. The work done when a force of one **newton** produces a displacement of one meter in the direction of the force.

$$1 J = 10^7 \text{ erg} = 0.2390 \text{ calorie.}$$

JOULE LAW. The quantity of heat generated by a steady electric current is proportional to the resistance of the conductor in which the heat is generated, to the square of the current, and to the time of its duration: $H = KRI^2t$. If the resistance is in ohms, the current in amperes, the time in seconds, and the heat in calories, the constant K has the value 0.2390 calories/joule.

JOULE-THOMSON COEFFICIENT. The ratio of the change in temperature to the change in pressure when a gas expands at

constant **enthalpy** to a lower pressure through a small aperture or porous plug.

JOULE-THOMSON EFFECT. In passing a gas at high pressure through a porous plug or small aperture, a difference of temperature between the compressed and released gas may be noticed. Hydrogen and helium become warmer and all other gases cooler at ordinary temperatures and pressures. This phenomenon is called the Joule-Thomson effect. It is due to the departure of real gases from the **ideal gas laws**. With a perfect gas no difference should be observed.

JOVIAN. Of or pertaining to the planet Jupiter.

JP-1 AND JP-2. Kerosene type jet fuels.

JP-3. A jet fuel consisting of a mixture of higher-boiling hydrocarbons. Its boiling point is 600°F, freezing point -76°F, and specific gravity 0.76. It is a high vapor-pressure form of JP-4, and is used in Navy land-based jet airplanes.

JP-4. A jet fuel consisting of a mixture of hydrocarbons similar to JP-3, but with slightly different burning characteristics. It is between gasoline and kerosene in its boiling point, which varies in the range of 250-600°F. Its freezing points is -76°F, and its specific gravity, 0.78. It is a complex mixture of paraffins, cycloparaffins, aromatics and olefins, with small amounts of nonhydrocarbons such as sulfur, oxygen, and nitrogen-compounds. It has the odor and appearance of kerosene. It is the most common **turbojet** fuel.

JP-5. Kerosene with a flash point of 140°F. It is used almost exclusively by U.S. Navy jets.

JP-6. Kerosene with good thermal stability and clean burning characteristics.

JPL. Jet Propulsion Laboratory; Pasadena, California.

JPT. A solid propellant used in the **M-8**, 4.5 inch rocket. It contains **diphenylamine**.

JPX. A mixture of 40% dimethyl hydrazine and 60% **JP-4**.

JRDB. Joint Research and Development Board.

JSPG. Joint Strategic Plans Group.

J-TYPE (INTRINSIC) SEMICONDUCTOR. A **semiconductor** in which the electrical properties are essentially not modified by impurities or imperfections within the crystal.

JUNCTION. (1) In a **semiconductor** device, a region of transition between semiconducting regions of different electrical properties. In a **waveguide**, a point at which provision is made for the flow of energy into two or more paths.

JUNCTION, COLLECTOR. In a **semiconductor** device, a junction normally biased in the high-resistance direction, the current through which can be controlled by the introduction of minority carriers.

JUNCTION TRANSISTOR. Transistor, **junction**.

JUNO I. Explorer.

JUNO II. The lunar probe vehicle consisting of a Jupiter booster first stage, and a solid propellant top stage or stages.

JUPITER. (1) (for data, see **planet**). Largest planet of the solar system. Its mean distance from the earth is approximately 395 million miles where it is visible to the naked eye. The gravitational acceleration on the surface of this planet is approximately 300 times that of earth. It has 12 moons, the largest of which is Europa, some 3,100 miles in diameter. Jupiter is 88,700 miles in diameter and is the fastest in rotation of the planets (period less than 10 hours). It revolves about the sun in approximately 2 earth years, and is at an average distance of 483 million miles from the sun. Its temperature has been estimated to be 210°F. Its atmosphere appears to consist of hydrogen, methane, water and ammonia. Jupiter changes color in an aperiodic manner. (See also **planet**.)

(2) The Jupiter missile is an Intermediate Range Ballistic Missile (IRBM) in a development program conducted by the U.S. Army Ballistic Missile Agency, Huntsville, Alabama. The missile project was initiated in the fall of 1955 along with the **Thor** (IRBM #1), which was assigned to the Air Force with civilian development by the Douglas Aircraft Co. The Jupiter program was revised

in 1956 to a joint Army-Navy project in order to make the missile suitable for submarine use. In 1957, the Navy realized that the liquid propellant system of Jupiter made it unsuitable for submarine use and initiated the **Polaris**, a solid-propellant, two-stage vehicle to be developed by the Lockheed Aircraft Co.

Several months later (November, 1956), Mr. Wilson, then Secretary of Defense issued a memorandum allowing the Army to have missiles up to 200-mile range and assigning the Air Force responsibility for all surface-to-surface operational use beyond this range. The memorandum authorized the continuance of the Jupiter program.

The Jupiter missile grew out of the well-matured Redstone program. The guidance system was easily converted to the Jupiter, and the Redstone vehicle was immediately available to begin flight test of Jupiter components. Published reports indicate that there were at least three different types of missiles used during the Jupiter development. The Jupiter (SM-78) is a Chrysler-Arma development by U.S. Army, for the U.S. Strategic Air Command. It has a nuclear warhead, a range of 1500 miles, a length of 58 ft., and a diameter of 8 ft. 9 in. It is a single-stage; it is launched vertically; its auto-

pilot turns to ballistic trajectory when inertial guidance takes over. Its airframe is made by Chrysler; its propulsion system, by North American Rocketdyne; its guidance by Sperry Rand; and its nose cone by Goodyear Aircraft. (See **missile, guided**.) The Jupiter-A is a Redstone configuration, the Jupiter-C, is a Redstone with multistage unit on top, used for long range and re-entry tests. The first full-scale Jupiter was fired in March, 1957, at Cape Canaveral. The first completely successful Jupiter was the third round fired on 31 May 1957. On 20 September, 1956, a Jupiter-C vehicle reached an altitude of 650 miles and a range of 3,300 miles (15,000 mph).

The Army was directed in the early winter of 1957 to give support to the Vanguard earth satellite program by providing a back-up satellite launching capability. It was expected at that time that the Jupiter-C vehicle would be used. In December the Army announced that it would launch a satellite vehicle. On January 31, 1958, the Army Ballistic Missile Agency in combination with the Jet Propulsion Laboratory succeeded in putting up a 30.8 pound earth satellite, the Explorer I. (See for further details of this and later **Explorers**, see that entry.) (See illustration facing Page 250.)

K

K. (1) Proportionality constant in force-mass equation (K). (2) Torsion constant, or torque per unit twist (k). (3) Unit vector in Z-direction (\mathbf{k}). (4) Miller index (h,k,l). (5) Degree Kelvin ($^{\circ}\text{K}$). (6) Reaction velocity constant (k). (7) Luminous efficiency (K); monochromatic luminous efficiency ($K\lambda$). (8) Magnetic volume susceptibility (k). (9) Mass transfer coefficient (K or k). (10) Thermal conductivity (k). (11) Compressibility factor (k). (12) Equilibrium constant (K). (13) Boltzmann constant (k). (14) Curvature (K). (15) Force constant (k). (16) Radius of gyration (k). (17) Kerr constant (K). (18) Spring constant (k). (19) Grid conductance, at 0 frequency and constant plate potential (k_g). (20) Potassium (K). (21) Proportionality constant in Coulomb's law (K_e). (22) Proportionality constant in law of attraction between currents (K_m). (23) Compressibility factor in aerodynamics (k). (24) Ratio of propellant surface area to nozzle throat area (k). (25) Nozzle area ratio (K).

K-24. A U.S. Air Force camera. Originally designed for aircraft use, it has been adapted to ground use, for which it is usually tripod-mounted. The camera has a 5 x 5 inch frame, and can operate at a rate of 3 exposures per second, with shutter speeds of $\frac{1}{150}$, $\frac{1}{450}$ and $\frac{1}{900}$ second. Lenses of 7, 12, and 20-inch focal length are used.

K BAND. A radio frequency band of 11,000 to 33,000 mc/sec with a corresponding wave length of 2.7 to 0.9 cm.

KAN-1. A U.S. Navy surface-to-air missile developed during World War II for use against the Japanese Kamikaze air attacks. It was popularly called Little Joe. Propulsion was by a solid-fuel rocket with RATO booster units (4) attached outside the body for take-off. Its configuration was a small barrel-shaped body with four rectangular fins at the tail, and four smaller fins in a canard arrangement at the very nose (these were in-

line with the tail fins). It was launched from a short ramp. It was never used tactically.

KAN-2. A later version of the KAN-1.

KAPL. Knolls Atomic Power Laboratory; Operated by General Electric for the Atomic Energy Commission; Schenectady, New York.

KATIE. A rocket for launching from large-size naval guns.

kg. Kilogram.

KARMAN CONSTANT. An absolute constant introduced by von Karman in his similarity theory of turbulence. In turbulent boundary layers sufficiently close to the boundary, the rate of shear $\partial U / \partial y$ is related to distance from the boundary y by

$$\frac{\partial U}{\partial y} = \left(\frac{r_0}{p} \right)^{1/4} \frac{1}{Ky}$$

where r_0 is the shear stress at the wall, p is the fluid density, K is the Karman constant. The best available value of K is 0.41 ± 0.01 .

KARMAN STREET OF VORTICES. Beyond a critical flow **Reynolds number**, the laminar wake of a long cylinder is unstable and develops into a double row of diffuse vortices, arranged alternately in two rows as are street-lamps. T. von Karman investigated the stability of a double row of line vortices in an inviscid fluid, and showed that only one alternating arrangement is stable, and that the computed ratio of spacing of the vortices to separation of the rows agrees well with observation.

KARMAN-TSIEN RELATION. A theoretical relationship of the Mach 1 pressure coefficient to the corresponding pressure coefficient at low speed. The relationship takes into account the compressibility effects of high speeds. It gives a better correlation with experimental findings of actual pressure coefficient than the **Glauert theory**. The pres-

sure coefficient according to the Karman-Tsien relation is:

$$C_p = \frac{C_{p0}}{\sqrt{1 - M_1^2} + \frac{1}{2}C_{p0}[1 - \sqrt{1 - M_1^2}]}$$

where C_p is the pressure coefficient at Mach 1, and C_{p0} is the low speed pressure coefficient. The above relation refers to two-dimensional flow. (See also **compressibility**.)

KATABATIC WIND. A cold air drainage downhill toward lower terrain. In desert ravines katabatic winds attain high local velocities.

KATUSHA. A Soviet World War II rocket approximately six feet long and five inches in diameter with a sharp pointed nose. Two types of launchers were used: ground mounts and truck mounted racks (using Lend-Lease Studebakers) with 8 double racks fitted to each truck allowing 16 rockets to be fired simultaneously.

KATYDID. A U.S. Navy target drone developed after World War II. Its official designation was **KDD-1**, from which the popular name Katydid was derived.

KDD-1. A U.S. Navy **target drone** developed by the McDonnell Aircraft Corporation. It was 11 feet long and had a wing span of 12 feet. The power source was a McDonnell-Schmidt pulsejet (7-inch diameter and 6-foot length) mounted on top of the body. The configuration was a mid-wing monoplane with a narrow "V"-tail. The pulsejet exhausted between the tails. It was radio-controlled, and had a capability of 40 minutes of flight.

KDM-1. A U.S. Navy **target drone** used for antiaircraft gunnery target practice. It was called the "Plover" and was made by the G. L. Martin Company. It was a radio-controlled ramjet type vehicle having the appearance of an inverted V-1. It was actually a form of the **Gorgon IV**. The KDM-1 differed from the Gorgon IV in that it had swept-back wings. It used a Marquardt ramjet engine and traveled at high subsonic speeds.

KEEP-ALIVE VOLTAGE. A voltage used in a radar **transmit-receive** box to enable an arc to occur at low radio-frequency voltages.

KELVIN TEMPERATURE. **Temperature.**

KENNELLY-HEAVISIDE LAYER. **Ionsphere.**

KEPLERIAN LAWS OF PLANETARY MOTION. After years of labor in attempting to develop a theory of planetary motion which would satisfy the accumulation of planetary positions determined by Tycho Brahe, Johann Kepler decided to abandon the superstition that the circle is the only perfect curve and hence must be followed by the planets. In the early part of the 17th century he announced three fundamental laws of planetary motion which satisfied Tycho's observations. These laws may be stated as follows:

1. Each planet moves in an ellipse with the sun at one focus.

2. The radius vector of each planet passes over equal areas in equal intervals of time. (The law of areas.)

3. The square of the period of revolution of a planet about the sun is proportional to the cube of the mean distance of the planet from the sun.

When first published, the laws were without theoretical foundation, being empirically derived from observational data. They created a tremendous stir and were declared heretical since they abandoned the circle as the only possible path for a planet. About 50 years later **Newton** was able to show that the laws are a direct consequence of motion under the action of the law of universal **gravitation**. They are discussed further under **planetary orbit theory**.

KERNEL. In mathematics, a function of two sets of variables used to define an integral operator. If the integral operator so defined is the inverse of a differential operator, the kernel is known as the Green's function belonging to the differential operator. (Diffusion kernel or Yukawa kernel: a Green's function of the elementary diffusion equation; slowing-down kernel: the probability that a neutron will go from one position to another while slowing down through a specified energy range.)

KERR CELL. A cell with electrodes which can hold a suitable dielectric fluid for observing the **Kerr effect**. By placing such a cell between crossed **nicols**, a pulse of light of very short duration may be passed by applying a potential difference to the electrodes for a very short time.

KERR EFFECT. Many isotropic substances when placed in an electric field behave like a uniaxial crystal with the optic axis in the direction of the field. If n is the index of the substance in the absence of the field and n_p and n_s are the indices for the magnetic vector parallel and perpendicular to the field, it is shown that $n_p - n_s = \lambda KE^2$, Kerr law, where K is the Kerr constant and E is the electric field strength. The relation $n_p - n = 2(n_s - n)$ is the Havelock law. The effect has been applied to high speed cameras for use in lieu of shutters to permit exposures of the order of one ten-millionth of a second.

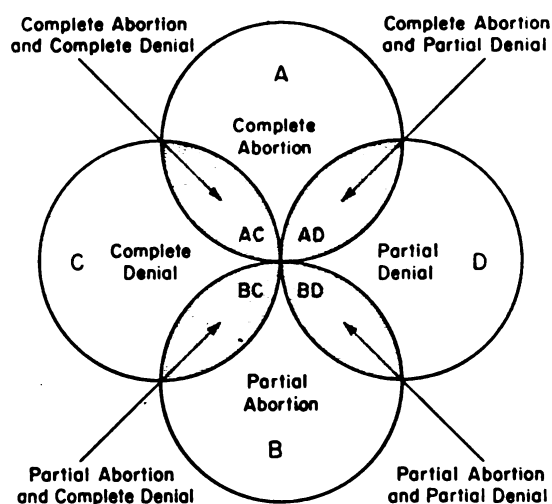
KEV. Abbreviation for 1000 electron-volts, a unit of energy.

KEYING. The formation of signals, as those used in telegraph transmission, by an abrupt modulation, such as results from interrupting the carrier or suddenly changing its amplitude or frequency (or any other characteristic). Keying is normally effected in a logical manner in accordance with some intelligence to be transmitted.

KILL. The achievement of a desired effect against an enemy target.

Symbol	Kill	Definition
A	Complete abortion	The enemy attack is less than 1% effective as compared with an unopposed successful attack
B	Partial abortion	The enemy attack is thwarted so that his destructive effect is reduced, but not as much as for complete abortion.
C	Complete denial	The enemy force or resource attacked is completely destroyed or made unavailable to him for use in further war activity.
D	Partial denial	The enemy force or resource attacked cannot be used in further war activity unless repaired or replaced in part, or until after a lapse of time.

(See **abortion; attrition; K-kill.**) (See Figure below.)



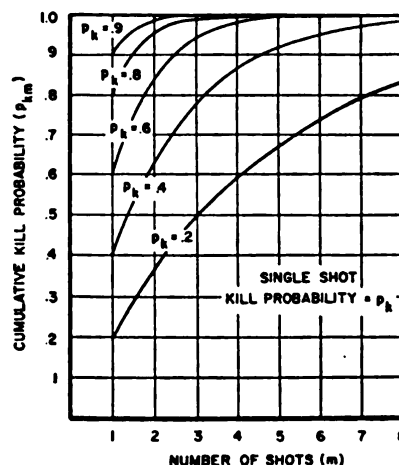
Four basic types of kill and their combinations.

KILL MEASURE (RANK). The order of desirability of several kills.

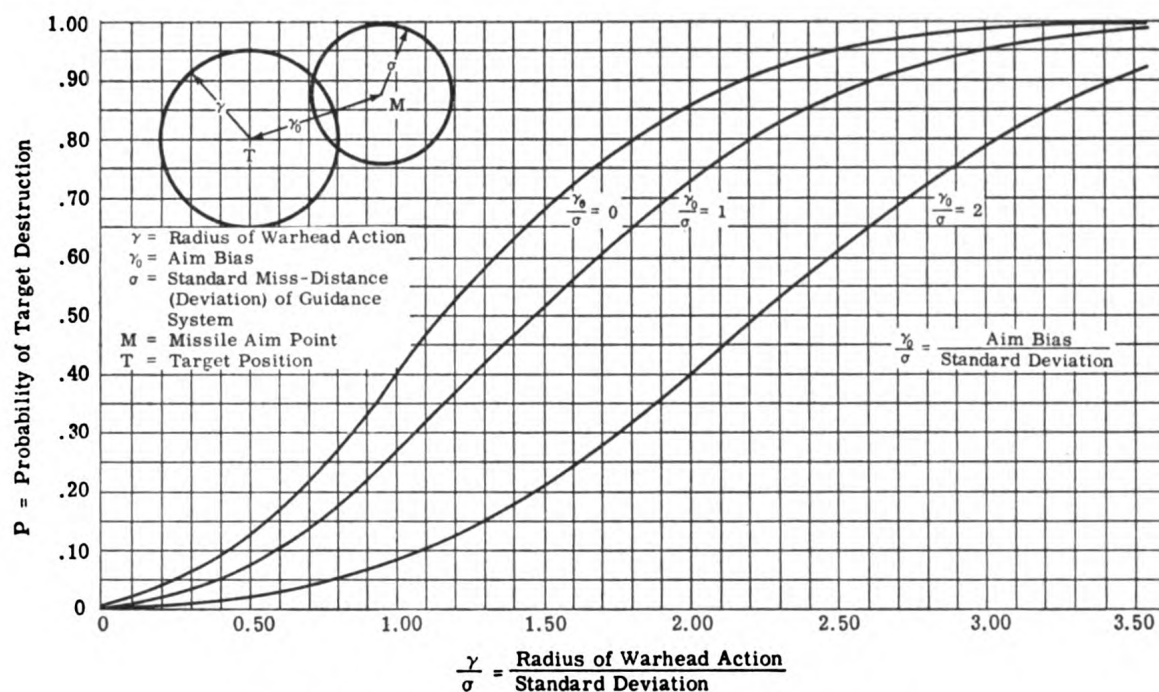
KILL PARAMETER. A test situation, circumstance, or condition which requires that a test run be terminated immediately.

KILL PROBABILITY. (1) The chance that a target will be destroyed by a given operation. (2) The likelihood of producing the desired kill under the conditions specified. Kill probability is a function of guidance accuracy and the radius of warhead action as seen in the Figure on Page 343.

KILL PROBABILITY, CUMULATIVE. If the single-shot probability is P_k , the P_{km}



Cumulative kill probabilities after several firings.



Relationship of armament effectiveness and guidance accuracy.

which results (assuming no progressive damage) from firing m shots at the target is:

$$P_{km} = 1 - (1 - p_k)^m$$

(See Figure at bottom of Page 342.)

KILO- A prefix used with many physical units, denoting one thousand. Thus 1 kilometer = 1000 meters; 1 kilowatt = 1000 watts.

KILOGRAM. (1) Unit of mass, abbreviation K or Kg. A mass equal to that of the International prototype kilogram, a platinum body kept at Sevre.

(2) Unit of force. The weight of one kilogram mass. When extreme precision is needed, it is specified that this weight shall be measured at a point on the earth's surface where the acceleration due to gravity is exactly 9.80665 meters/sec².

KILOGRAM METER. A unit or work in the gravitational system defined as the work done in raising a mass of one kilogram through a distance of one meter against gravity. It equals 98,066,500 ergs.

KILOWATT. A unit of power—defined as 1000 watts—which ordinarily serves as the commercial measure for electrical power. Electrical power of one kilowatt used steadily

for one hour involves an energy consumption of one kilowatt-hour. A kilowatt is equal to about 1.34 hp.

KINEMATIC VISCOSITY. The viscosity of a fluid divided by its density; a parameter which measures the acceleration of a fluid resulting from distortion, and is therefore important in aerodynamic calculations. A few values for air at standard sea level pressure are:

TEMPERATURE	KINEMATIC VISCOSITY
(°C)	(ft ² /sec)
0	1.432×10^{-4}
100	2.474×10^{-4}
200	3.724×10^{-4}
400	6.723×10^{-4}
500	8.446×10^{-4}

(See also **Reynold's Number**.)

KINEMATICS. The science of motions considered in themselves, or apart from their causes. (See **kinetics**.)

KINESCOPE. In television, the cathode ray tube when used as the picture tube in a television receiver. (The camera tube is called the iconoscope.)

KINETIC ENERGY. Energy of motion. A simple course of reasoning based on **Newton's laws of motion** leads to the formula $E = \frac{1}{2}mv^2$ for the kinetic energy (in absolute units) of a mass m moving with a speed v . Thus a stone of mass 100 grams moving with a speed of 1000 cm per sec has $\frac{1}{2} \times 100 \text{ g} \times 1000^2 \text{ cm}^2/\text{sec}^2 = 50,000,000 \text{ g cm}^2/\text{sec}^2$ (or ergs) of kinetic energy. When the moving body is brought to rest by a force of average value f , and continues to move a distance, d , after this force is applied, it does an amount of work, fd , equal to its kinetic energy $\frac{1}{2}mv^2$. If d is very small, f must be large. Thus, if the stone in the above example were stopped in a space of 0.01 cm (as in striking a hard obstacle), we should have $0.01 \text{ cm} \times f = 50,000,000 \text{ g cm}^2/\text{sec}^2$, or $f = 5,000,000,000 \text{ g cm}/\text{sec}^2$ (or dynes), which is equivalent to 5100 kilograms or more than 5.6 tons.

The kinetic energy of a body rotating with angular speed ω (radians per sec) about an axis for which its moment of inertia is I , is $E = \frac{1}{2}I\omega^2$; or $2\pi^2In^2$, where n is the number of rotations per sec. The theory of **relativity** gives slightly higher values for the kinetic energy, but the differences are negligible except for very great speeds.

KINETIC THEORY. A theory (proved by direct experiment) which explains the phenomena of heat as due to the kinetic motion and elastic collisions of atoms and molecules.

KINETICS. The branch of **dynamics** that treats of changes of motion produced by forces.

KINGFISHER. A U.S. Army target **drone** developed by Lockheed Missile Systems Division. It has a cylindrical body about 35 ft. long, with needle nose, and swept midwing with tapered leading and trailing edges.

K-INTERNAL. The ratio of propellant surface which must discharge past any constricted region to the area of that region, at the most constricted portion of a rocket motor.

KIRCHHOFF'S CURRENT LAW. A fundamental electrical law which states that the sum of all the currents flowing to a point in a circuit must be equal to the sum of all the currents flowing away from that point.

KIRCHHOFF'S VOLTAGE LAW. A fundamental electrical law which states that the

sum of all the voltage sources acting in a complete circuit must be equal to the sum of all the voltage drops in that same circuit.

KIWI-A. A **nuclear energy** powered test rocket engine under study at Los Alamos Scientific Laboratory.

KLYSTRON. A vacuum tube for converting direct-current energy into radio-frequency energy by alternately slowing down and speeding up an electron beam, utilizing the transit time between two points to produce a velocity-modulated electron stream to deliver radio-frequency power to a cavity resonator. The term is applicable to an ultra-high-frequency amplifier, or generator, that combines the velocity-modulation principle with one or more cavity resonators to produce and/or utilize a velocity-modulated beam of electrons.

K-KILL. A standardized term which classifies the damage inflicted upon an aircraft target by a missile. For a K-Kill the aircraft must fall out of control without a reasonable doubt. It is a specialized case of the general A-Kill which applies to all targets. (See **kill**.)

Km. Kilometer.

KNOT. A velocity of one nautical mile per hour, i.e., 1.1516 statute miles per hour. It is *not* a measure of distance.

Kr. Krypton.

KTH-53. A model (1953) of the German Askania **cinetheodolite**.

KTH-55. A **cinetheodolite** made by the Perkin-Elmer Corporation. It is operated by 1-2 men and is capable of being synchronized with other cameras for photogrammetric determinations. It normally has a 40-cm focal length but can also be obtained in 60-cm, 48-inch and 60-inch catadioptric systems.

KUD-1. A U.S. Navy radio controlled glider bomb developed by McDonnell Aircraft Corporation. It had the appearance of a small low-wing monoplane (with slight dihedral and a low-angle dihedral "V" tail). It was better known by the popular name **Gargoyle**. It used a solid propellant rocket engine and had a top speed of 600 mph. Payload was a 1000

pound general purpose bomb. It was never used in combat.

KUW-1. A U.S. Navy missile adapted from the **JB-2**.

kw or KW. Kilowatt.

KYTOON. A captive balloon with kite-like aerodynamic surfaces which has the property of maintaining an almost constant altitude. It is frequently used to support an antenna required to be elevated to a relatively high altitude above the ground.

L

L. (1) Relative heat constant (L). (2) Latent heat per unit mass (l). (3) Levorotatory (l -). (4) Length (l or L). (5) Rest length (l_0). (6) Heat of vaporization (L). (7) Liter (l). (8) Direction cosine (l, m, n). (9) Free path or mean free path (l or λ). (10) Tait free path (l_T or λ_T). (11) Length of heat flow path (L or l). (12) Lagrange function (L). (13) Inductance (L). (14) Mutual inductance (L_{12}). (15) Rolling moment (L). (16) Characteristic length (propulsion) (L^*).

L-2, L-10, L-11, L-30, L-40, L-50 and LT-950. A series of glide-torpedoes designed by the Germans during World War II. They were all air-to-water missiles similar to the German LT-1 aerial torpedo with various modifications.

L BAND. A radio frequency band of 390 to 1550 megacycles per second with corresponding wave lengths of 77 to 19 cm.

La. Lanthanum.

LACROSSE. A U.S. Army solid propellant surface-to-surface guided missile, made by the Martin Company, after development by the Cornell Aeronautical Laboratory. It was announced in 1956. Statements at that time said that it used a Thiokol solid rocket and was launched from a standard Army truck. In 1957 it was announced that it was an anti-fortification and antitank weapon with a 15-20 mile range. Its dimensions were: 20 feet in length, 20.5 inches in diameter, wingspan of 108 inches, tailspan of 87 inches, and weight of several hundred pounds. Its official designation was: SSM-A-12. (See **missile, guided.**) (See also illustration facing Page 250.)

LAG, ANGLE OF. When two related quantities, such as an alternating voltage and an alternating current, vary sinusoidally with time and have the same frequency, they may be expressed as

$$Q_1 = A \left\{ \frac{\sin}{\cos} \right\} (\omega t + \phi)$$

$$Q_2 = B \left\{ \frac{\sin}{\cos} \right\} \omega t$$

where A , B , and ω are constants. It is then said that Q_2 lags (behind) Q_1 and ϕ is known as the angle of lag if it is positive. If ϕ is negative its magnitude is the angle of lead and Q_2 is said to lead Q_1 .

LAGGING CURRENT. Opposite of leading current.

LAGRANGE EQUATIONS (SOMETIMES CALLED EULER-LAGRANGE EQUATIONS). A set of equations of motion for a dynamic system. In the case where the system is conservative the equation of motion for the i th particle is written:

$$\frac{d}{dt} \frac{\partial L}{\partial \dot{q}_i} - \frac{\partial L}{\partial q_i} = 0$$

where L is the Lagrangian function of kinetic potential; q_i is the generalized coordinate of i th particle ($i = 1, 2, 3, \dots, n$, where n is the number of **degrees of freedom** of the system); \dot{q}_i is the generalized velocity of i th particle.

These equations have the advantage over Newton's equations that any kind of coordinates may be used.

For non-conservative systems a set of equations can be written:

$$\frac{d}{dt} \frac{\partial K}{\partial \dot{q}_i} - \frac{\partial K}{\partial q_i} = Q_i$$

where Q_i is the generalized force such that $Q_i \delta q_i$ represents work done by Q_i when the coordinate q_i changes by δq_i ; K is the kinetic energy of the system.

LAGRANGIAN EQUILIBRIUM POINT. A point in space where the resultant gravitational field is zero. This condition may be produced by the equilibrium between the gravitational fields of two or more bodies, or it may be experienced by a body in a free-



The U.S. Army's REDSTONE shown on the occasion of the activation of the 40th Field Artillery Missile Group. The giant surface-to-surface missile, armed with an atomic or conventional warhead, is employed to increase the firepower and extend the range of artillery cannon. Some 69 feet in height, it carries a self-contained guidance system which, with its supersonic speed, makes it completely immune to known types of counter-measures. Firing panel (above) set up in a foxhole continues to monitor the REDSTONE system. (*U.S. Army Photograph*)



The REGULUS, a Navy guided missile, is launched from the stern of the USS Helena (CA-75) during tests conducted off the coast of southern California. (*U.S. Navy Photograph*)



The Navy's REGULUS II surface-to-surface missile is shown during a test firing. Two versions of the missile have been developed for the Navy by the Chance Vought Aircraft Company. (*U.S. Navy Photograph*)

fall orbit, where its angular acceleration is equal and opposite to the acceleration of the resultant gravitational field. Theoretically, of course, every body has an infinite gravitational field; the Lagrangian Equilibrium Point is therefore limited in its validity to the gravitational fields which are assumed to be significant.

LAMBDA SHOCK. In supersonic aerodynamics, a **shock wave** shaped like the lower case Greek letter lambda (λ). It is also called a **bifurcated shock wave**.

LAMBERT. A unit of **luminance** equal to $1/\pi$ **candle** per square centimeter, and, therefore, equal to the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of one **lumen** per square centimeter.

LAMBERT CONFORMAL PROJECTION. In cartography, a means for portraying the earth's surface. A cone is placed over a sphere representing the earth, with the axes of the cone and of the sphere in coincidence. The size of the cone is such that it cuts the surface of the sphere at the two parallels representing the parallels of latitude which have been selected as the standard parallels of the projection. The meridians of the sphere are projected onto the cone and so determine the meridians of the chart. The land masses on the sphere are then projected onto the cone. In the Lambert conformal projection the area lying between the standard parallels is compressed and the area lying outside the standard parallels is expanded.

Standard parallels are arcs of concentric circles with the apex of the cone as a center. The area between the standard parallels may be further divided by swinging additional arcs for other parallels of latitude. The meridians are straight lines converging at the apex of the cone.

Advantages of Lambert Conformal Projection:

(a) The distortion is comparatively minor. There is no distortion along the standard parallels.

(b) The same distance scale may be used anywhere on the chart, with negligible error.

(c) Meridians and parallels intersect at right angles and the angles formed by any two lines on the surface of the earth are correctly represented on the chart.

(d) A straight line on the chart closely approximates a great circle. The Lambert conformal projection thus also closely satisfies the requirements for missile guidance use.

LAMINA. (1) In general, a sheet of material. (2) A layer of the atmosphere between designated altitudes. (3) Any one of the separate sheets of airflow or flow of other fluid making up a **laminar flow**.

LAMINAR BOUNDARY LAYER. A boundary layer characterized by **laminar flow**.

LAMINAR FLOW. Fluid flow.

LAMINAR-FLOW AIRFOIL. An airfoil specially designed to maintain **laminar flow** about itself, especially at transonic or supersonic speeds.

LAMINAR SEPARATION. Separation that exists when a **laminar boundary layer** leaves the surface of the **airfoil** and moves into the free fluid.

LANAC. An abbreviation for: *Laminar Navigation Anti-collision*. It is a system of air and ground radars and associated beacon equipment used for flying safety.

LANCHESTER DAMPER. A mechanical damper used in servos and mechanical systems in which the damping element is a fly-wheel; the damper depends on the acceleration forces required to rotate the wheel for the damping. The wheel is sometimes submerged in oil to provide additional damping.

LAND. The surface between adjacent grooves of a phonograph record or of a **diffraction grating**. The term also applies to the high spots in an incompletely ground or polished optical surface.

LANDING BEACON. A radio transmitter used to generate a **landing beam**.

LANDING BEAM. A radio beam, highly directional in both elevation and azimuth, used to guide aircraft to safe landings during poor visibility conditions.

LANTHANUM. Rare earth element. Symbol La. Atomic Number 57.

LAPLACE EQUATION. A second-order partial differential equation which, in vector form, is $\nabla^2\phi = 0$ or in rectangular coordinates,

$$\frac{\partial^2 \phi}{dx^2} + \frac{\partial^2 \phi}{dy^2} + \frac{\partial^2 \phi}{dz^2} = 0.$$

It is the homogeneous case of Poisson's equation. Its solutions, the scalar quantity ϕ , occur in problems involving steady-state temperatures, gravitational and electric potentials, hydrodynamics of ideal fluids, and many other physical phenomena. The equation is usually solved by the method of separation of variables in a suitable curvilinear coordinate system and with boundary conditions imposed by physical requirements. Such solutions are called harmonic functions. In two dimensions, an analytic function of the complex variable must satisfy Laplace's equation.

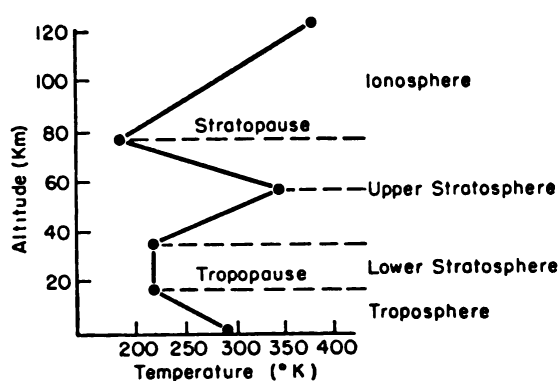
LAPLACE TRANSFORM. A method in transformation calculus used to solve linear equations containing both integrals and differentials. It simplifies integro-differential equations into algebraic equations by the use of complex numbers. Symbolically:

$$\mathcal{L}[f(t)] = \int_0^{\infty} f(t) e^{-st} dt = F(s)$$

(where $s = \sigma + j\omega$)

This transform is particularly useful in servo system analysis.

LAPSE RATE. The rate of change in value of a meteorological phenomenon, usually the rate of decrease of pressure or more commonly, temperature, with elevation. (See figure.) (See **normal lapse rate**, **standard pressure lapse rate**.)



Atmospheric lapse rate.

LAR. Liquid aircraft rocket.

LARK. A missile developed in one form by the Guided Missiles Division of the Fairchild

Engine and Airplane Company and in another by CONVAIR and the Raytheon Manufacturing Co. It was used by all U.S. armed services both as a training missile, and as a flight test vehicle. It was a cylindrical missile approximately 14 feet long, weighing 1210 pounds at take-off. It had four wings near the center of the body (in cruciform) and four **interdigitated** tail surfaces in the rear. The wings were vertical and horizontal, and the tail surfaces inclined at angles of 45 degrees to them, so that they gave the impression of being out of track. All the aerodynamic surfaces were rectangular, and each carried trailing-edge control surfaces. The wing surfaces provided directional steering. The tail vanes controlled flight attitude. Extensible ailerons, normally retracted, operated to check any roll tendency. Two Aerojet General JATO units were used for boost. These were inside a large box fin attached behind the tail. The main power unit was a RFNA-aniline type having two combustion chambers, made by Reaction Motors Incorporated. One chamber burned continuously as a sustainer, and the second motor was used only when executing maneuvers. Lark used a radar homing guidance system. It was fired in large numbers in 1950-1953 and was the first known anti-aircraft missile to intercept and destroy a target drone. The Navy official designation for the missile was CTV-N-9.

LATCH. A device designed to fasten a rocket in or on a launcher prior to firing.

LATE ARMAMENT. Armament which functions after the target has been passed and, therefore, cannot be damaged.

LATE BIRD. A missile which arrives at the intersection of the missile-target trajectories after the target has passed the intersection and is out of the damage volume of the missile.

LATERAL ATTITUDE. The attitude of an aircraft, rocket, etc., with respect to its lateral axis.

LATERAL STABILITY (AND CONTROL) COEFFICIENTS. Stability (and control) coefficients; stability, lateral.

LATITUDE. (1) The latitude of a point on the surface of the earth is its angular distance north or south of the equator. It is also the

angle at the earth's center subtended by the arc of the meridian contained between the equator and the point. Latitude is measured numerically in degrees north and south of the equator. Measurements of latitude are based upon a local vertical reference. If a plumb bob or spirit level is used for the determination of this vertical, there is likely to be another error, since the magnitude and direction of the gravitational attraction changes from place to place. Astronomical (and celestial) latitude is based upon the apparent vertical. Geodetic latitude is based upon the true vertical. (2) In astronomy, the angular distance of a celestial body from the ecliptic.

LAUNCH. (1) To release or send forth, under its own power only, a rocket, guided missile, or the like from a special launcher, rack, ramp, or other device or installation.

LAUNCH AREA. Launch base area.

LAUNCH BASE AREA. For ground-launched missiles, a geographic area encompassing numerous command posts, launch stations and associated guidance stations, a control center, and a support base.

LAUNCH COMPLEX. The facilities and equipment required for launching a missile, including launcher, blockhouse, ground guidance, launcher servicing and other required ancillary equipment.

LAUNCH FLIGHT. Flight.

LAUNCH-LATCH. (1) A device which locks the S and A and which is released at missile takeoff. (2) A device which restrains a missile until the proper conditions for its launching have been achieved.

LAUNCH PAD. A specific facility from which one missile at a time can be launched. In general, this is a 100 by 200-foot reinforced concrete slab with underground access tunnels or trenches to the blockhouse. In a typical tunnel is found power monitor and firing circuit cables, and emergency power equipment.

LAUNCH PHASE. In missile kinematics, that portion of the trajectory from takeoff through booster burn-out. For multi-stage missiles, it is the period from takeoff to first stage burn-out. For aerodynamically sup-

ported missiles the launch phase is the period to booster burn-out and separation, or where no boost is used, it is some arbitrary period until flying speed is attained. (See also **mid-course phase** and **terminal phase**.)

LAUNCH POINT. The point at which a missile or rocket is launched.

LAUNCH SITE. The location of a launch complex.

LAUNCH STATION. One or more launchers with associated storage, assembly, and maintenance facilities.

LAUNCH STATION AUGMENTED. A launch station with facilities for launching two or more missiles.

LAUNCHER. (1) A device for launching or catapulting an airplane, rocket or missile. (2) A device or installation from which a self-propelled missile, such as a ballistic missile, an aircraft rocket, or guided missile, is launched, usually incorporating a rail, tube, or the like for giving the missile initial guidance. See **rocket launcher**, **tower launcher**.

LAUNCHER ADAPTER. A device that fits rigidly to an aircraft rocket launcher to adapt it to the firing of rockets of a caliber different from that for which the launcher was originally designed.

LAUNCHER AND MISSILE STORAGE STRUCTURE, SURFACE OR UNDERGROUND. A single structure combining the functions of the launcher and the missile storage structure.

LAUNCHER, RAIL-TYPE. A structure supporting a set of rails which in turn support the missile-jato combination. The rails provide orientation and control during the early portion of the launching phase.

LAUNCHER, RETRACTABLE. A launcher designed to carry a missile in one position and extend it to a new position for launching.

LAUNCHER, UNDERGROUND. Underground launcher.

LAUNCHER, ZERO LENGTH. A launcher which supports the missile in the desired attitude prior to booster ignition, but which

exercises negligible control on the direction of the missile's travel after ignition.

LAUNCHING. (1) As applied to guided missiles and space craft, the action of sending forth or starting. (2) The name sometimes applied to the process of transferring energy from a **coaxial cable** or transmission line to a **waveguide**.

LAUNCHING ANGLE. The angle between the horizontal and the longitudinal axis of a missile at the time of launching or firing.

LAUNCHING DISPERSION. The departure (usually but not necessarily, random) from the desired flight path which a guided missile takes during the **launching phase**.

LAUNCHING PLATFORM. The base upon which guided a missile rests during preparation and launching. In its simplest form it consists of a rotatable ring supported by four adjustable supports or legs.

LAUNCHING RACK. A skeletonlike structure, usually incorporating rails, from which something is launched.

LAUNCHING RAIL. A rail that guides, or aids in guiding, a rocket missile or other projectile in launching.

LAUNCHING RAMP. A ramp used for launching an aircraft or missile into the air.

LAUNCHING RETRO. **Retro Launching.**

LAUNCHING ROCKET. **Booster rocket; Jato.**

LAUNCHING SILO. A type of underground launcher.

LAUNCHING SYSTEM (NAVAL). That part of a ship's installation designed and installed for the purpose of providing a means for launching a missile on a desired trajectory at a desired time. It may be either a static type with the missile providing its own ejection power, or a catapult type in which the launcher powers or assists the missile take-off.

LAUNCHING TUBE. A tube used to guide a rocket missile or other projectile during launching.

LAY. In gunnery, a term meaning to orient the ordnance in the proper direction and ele-

vation for firing. To lay means essentially to point in the proper firing direction. The laying of a vertically launched missile consists of bringing it into a vertical position, and turning its reference direction, usually an element of the guidance system, into the proper direction of fire.

LAZY DOG. An antipersonnel missile announced by the USAF in 1954.

LBE-1. A U.S. Navy World War II experimental glide-bomb. It was a small low-winged monoplane with tricycle landing gear. The operational concept was to tow it by a parent tow plane to within gliding distance of the target. It was then dropped and guided by radio command and television intelligence to a collision. It was never used tactically.

LC PRODUCT. A ratio used in circuit design; the **inductance** in henries, multiplied by the **capacitance** in farads.

L/C RATIO. A ratio used in circuit design; the **inductance** in henries, divided by the **capacitance** in farads.

L/D. **Lift-over-drag ratio.**

LDT. **Linear differential transformer.**

LEAD. (1) Metallic element. Symbol Pb. Atomic number 82. (2) The action of aiming ahead of a moving target with a gun, bomb, rocket, torpedo or missile so as to hit the target, including whatever action is necessary to correct for deflection. (3) The **lead angle** which is (1) angle between the instantaneous line-of-sight from missile to target and the flight direction required for an intercept, (2) an angle used in electrical terminology, discussed under **lag, angle of**. (4) The distance between the moving target and the point at which the gun or missile is aimed.

LEAD ANGLE. (1) The angle between the line-of-sight to a moving target, and the line-of-sight to a point ahead of the target, at which point a missile is aimed so as to strike the target. A lead angle may include corrections for gravity, wind effects upon the missile, deflection effects caused by launching device motion and motion of the target. (2) For the use of this term in electricity, see **lag, angle of**.

LEAD AZIDE. A white crystalline powder, PbN_6 , used as a primer for explosives. In contact with copper it is a supersensitive explosive. It is used chiefly as a fuze detonator.

LEAD CONTROL. In servomechanisms, the control of the stability of feedback systems by use of lead networks.

LEAD PREDICTION. The act of directing a missile (or projectile) ahead of a moving target, leading in aim to a predicted collision point.

LEADING CURRENT. In electricity, when the current of an alternating system reaches its maximum value before the voltage does, it is called a leading current. The opposite case is called a "lagging current." The degree of lead is a matter of phase, or angle of lead (or lag). The lead (or lag) angle is the phase angle, expressed in degrees, that an alternating current leads (or lags) the voltage wave. The cosine of this angle is called the power factor.

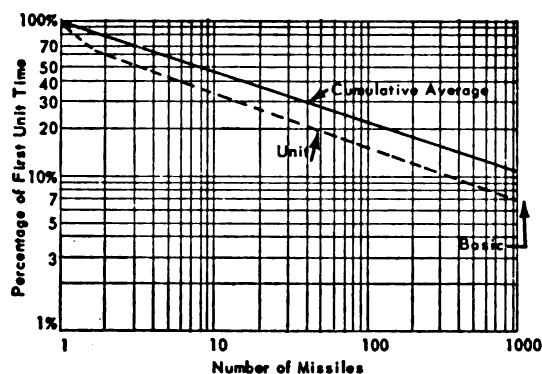
LEADING EDGE. (1) The front or entering edge of an airfoil. (2) The first portion of a pulse of electromagnetic energy; a sharp rise in energy is generally desirable.

LEADING-EDGE PULSE TIME. Pulse time, leading-edge.

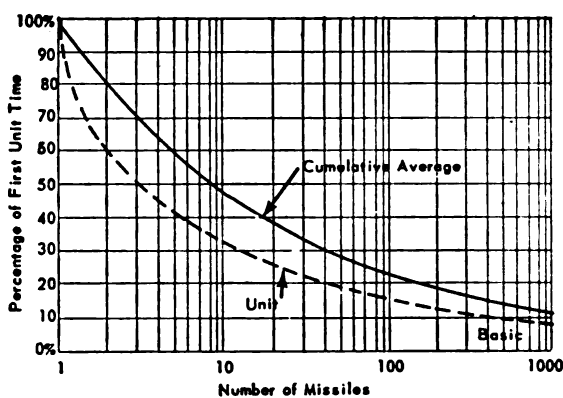
LEARNING CURVE. A graphic representation of the increase in proficiency of personnel with increase in experience; important in missile production and operations. (See figure.)

LEAST SQUARES FITTING. A method of combining experimental data which show the value of a dependent variable y for various values of the independent variable x in such a way as to establish the best relation between y and x . In the simplest and most common application, it is known that $y = a + bx$, where a and b are constants whose values are to be determined. The method leads to values of a and b such that the sum of the squares of the deviations of the observed values of y from the values predicted by the equation is minimized.

LE CHATELIER PRINCIPLE. A general law for physical systems: If a system is subjected to a constraint whereby the equilibrium



80% learning curve for direct labor as percentage of first unit time (log-log plot)



80% learning curve for direct labor as percentage of first unit time (semilog plot)

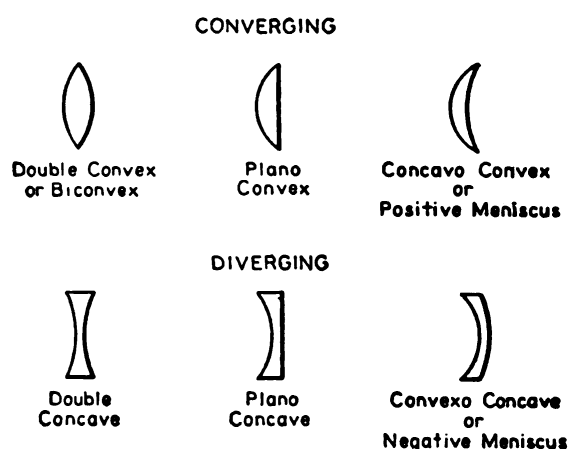
Learning curves.

is modified, a change takes place, if possible, which partially annuls the constraint.

LECHER LINE. A section of open-wire transmission line with two parallel wires a few centimeters apart, strung tightly between insulating supports. The arrangement is used for measuring the wavelength of a high frequency oscillator by the formation of standing waves. When a high frequency source is attached to Lecher wires, they oscillate in standing waves equal to the frequency of the source. By noting where maximum signal and nodes occur the wavelength can be measured directly. (Maximum signal occurs at the quarter-wave points, and nulls occur at the half-wave points.) A light bulb can be lighted if shorted across the Lecher line, and its brilliance used as an indication of the standing waves. It is more a demonstration device rather than a practical instrument for actual test purposes.

LENS. (1) An optical component consisting of one or more pieces of glass or other mate-

rial transparent to the radiation being used, which has the surfaces so curved, ordinarily spherical, that radiation coming from an object will, after passing through the lens, form an image, real or virtual, of that object. A simple lens consists of a single piece of transparent material. Simple lenses may be of any of these forms:



In the double-convex and double-concave cases, the two curvatures may be alike, equi-convex or equiconcave, or they may be different.

(2) In communications, a structure transparent to radio waves, and with a relative **dielectric constant** different from unity, designed in such manner as to produce a desired pattern. Such structures may employ dielectrics or metallic configurations. (See **antenna, lens**.)

(3) In electron optics, a configuration of electric or magnetic fields arranged to produce the desired electron-beam pattern.

(4) A magnetic lens is an arrangement of coils and magnets so disposed that the resulting magnetic fields produce a focusing force on a beam of charged particles.

LENZ' LAW. An induced current is always in such a direction that its field opposes any change in the existing field, or that the induced voltage is always in a direction opposing the applied voltage.

LEO (The lion). The **constellation** of Leo is one of the most easily distinguished of all of zodiacal constellations. The brightest star in the group, Regulus, is a **double star** but cannot be resolved with telescopes smaller than 3-in. aperture because of the fact that in

small instruments the bright star masks the fainter one. Gamma Leonis is one of the finest of the doubles with its two components of approximately the same magnitude, one yellow and the other orange in color.

The constellation is also noted for the location of the **radiant point** of the Leonids, one of the best known **meteor showers**.

LETHALITY. In military terminology, the probability that a given piece of ordnance will "kill" its target if it performs as designed. For example, an antiaircraft missile which is designed to explode by proximity fuze in the near vicinity of its target does not always cause the destruction of the hostile installation or vehicle for any of a large number of reasons. Therefore, the probability of a kill even for a "perfect" round at the target will be something less than 1.0.

LETHAL RADIUS. For a given target, the distance at which an **isotropic warhead** will almost certainly destroy the target.

LEVEL. The difference of a quantity from an arbitrarily specified reference quantity.

(1) In audio techniques, the quantities of interest are often expressed in decibels, thus their difference is conveniently expressed as a ratio. Hence, level is widely regarded as the ratio of the magnitude of a quantity to an arbitrary reference magnitude. (2) In television, level is (a), signal amplitude measured in accordance with certain specified techniques (see *IRE Proceedings* 39, May 1950); or (b), a specified position on an amplitude scale applied to a signal waveform, as the term is used in such definitions as reference white level and reference black level.

LF. Low frequency.

Li. Lithium.

LIBRA. (The scales or the balances.) Libra is a small constellation best known because it is the seventh sign of the zodiac and its symbol is taken for the autumnal **equinox** (i.e., the point where the sun apparently crosses the celestial **equator** from north to south). The brightest star in the constellation is a wide **double** which can easily be resolved by a field glass.

LIFE, HALF-. The time required for disintegration of one-half the atoms of a sample of

a radioactive substance. Its relation to the **disintegration constant** and the **mean life** is as follows:

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda} = 0.693\tau$$

where $t_{1/2}$ is the half-life, λ is the disintegration constant and τ is the mean life.

LIFE, MEAN. (1) In reliability engineering, the arithmetical mean (average) of the operating time between failures. (2) In physics, the average time during which an atom or other system exists in a particular form, e.g., the mean time between the appearance and disappearance (birth and death) of a particle. Five examples are: (a) The mean life of **mesons** before undergoing transformation. (b) The mean life of excited nuclei or atoms before losing their energy of **excitation**. (c) For a **radionuclide**, the mean life is the reciprocal of the **disintegration constant**. For branching decay, it is given by

$$\tau = \frac{1}{\lambda} = \frac{1}{\lambda_1 + \lambda_2 + \lambda_3 \dots}$$

where $\lambda_1, \lambda_2, \lambda_3, \dots$ are the partial disintegration constants for the various modes involved. (d) For a thermal neutron, the mean time interval between the instant when the neutron becomes thermal, and when it disappears from the reactor by absorption or leakage. For a homogeneous medium, the infinite and finite lifetimes refer to the lifetime in infinite- and given finite-sized regions of the medium. (e) When excess **carriers** are injected into a **semiconductor**, they will eventually recombine with others of the opposite sign.

LIFE TEST. A test under controlled conditions and specified environment to determine life expectancy of an equipment. The test is designed to establish the failure probability for a given sample size.

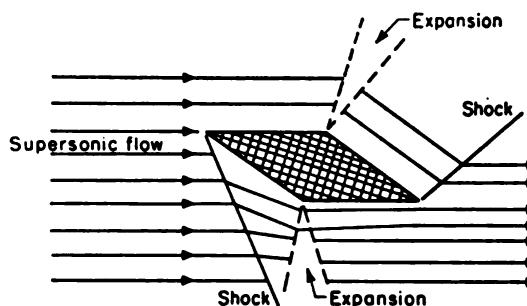
LIFT. That component of the total aerodynamic forces acting on an **airfoil** or on an entire aircraft or winged missile, perpendicular to the relative wind, and exerted, normally, in an upward direction, opposing the pull of gravity. Lift results from the flow of air over the surface. Its amount depends upon the contour of the surface, the angle of attack and the speed of travel through the air. If the relative air velocity is known, the formula for lift becomes (for incompressible flow):

$$L = C_L \frac{\rho v^2 S}{2}$$

Where L is the lift in pounds, S is the area of the airfoil in square feet, ρ is the mass density of the air in slugs per cubic foot, v is the velocity of the relative wind in feet per second and C_L is the coefficient of lift.

LIFT COEFFICIENT. Lift; **Aerodynamic coefficients.**

LIFT-DRAG RATIO. The ratio of the **lift** to the **drag** of any body, particularly of an **airfoil**, obtained by dividing lift by drag, or the lift coefficient by the drag coefficient. Often termed the “ L/D ratio” or, more simply, “ L/D .” It is a common measure of the aerodynamic merit of an airfoil.



Maximum lift-over-drag ratio for supersonic flow.

LIFT (DUE TO) DRAG. Drag.

LIFT-OFF. The event of a missile leaving the **launcher**.

LIFT-OVER-DRAG RATIO. In aerodynamics, the ratio of the **lift** to **drag** of the body in question. The ratio is also called the aerodynamic efficiency and is equivalent to the ratios of the coefficients of lift and drag: C_L/C_D . The lift-over-drag ratio is normally symbolized by L/D . In supersonic flight, the optimum condition of L/D occurs when two of the four flat surfaces of a double wedge airfoil are exactly along the wind direction. A subsonic lift-over-drag ratio can be as high as 30:1. A typical supersonic L/D for a bi-convex wing of infinite aspect ratio might be 7:1. (See figure.)

LIGHT, CIRCULARLY-POLARIZED. Discussed under **light, elliptically-polarized**.

LIGHT CURVE. In the study of **variable stars** and in kindred problems in **astronomi-**

cal research, it is desirable to represent graphically the variation of radiation intensity with time. A diagram in which light intensity, on any convenient scale, is plotted as ordinate against time as abscissa is known as a light curve. As the number of observations increases it is frequently possible to detect a periodic variation in the light intensity. After a provisional period has been determined, some convenient epoch is selected and all of the observations are reduced to the cycle of variation embracing the selected epoch by the use of the provisional period. In order that the resulting points may fall on a regular curve, it is frequently necessary to apply a number of corrections to the provisional period. The curve drawn through the plotted points, all reduced to the selected epoch by means of the repeatedly corrected period, is known as the mean light curve. Examples of light curves will be found in the articles on **long period variables** and on **Cepheids**.

LIGHT, ELLIPTICALLY-POLARIZED.

Given a thin section of **double-refracting** crystal with the optic axis of the crystal parallel to the face of the section. If now a beam of plane-polarized light (see **light, plane-polarized**) is incident normally on a face of the section with the plane of vibration of the incident beam making an angle A with the optic axis of the crystal, the beam will be divided into two components, the ordinary and the extraordinary, which travel with different speeds. Upon emergence, the two components will, in general, have different phases and will combine to form elliptically-polarized light. If the retardation in phase corresponds to an even number of half-wavelengths difference in path, the ellipse will degenerate into a line parallel to the incident plane of vibration. If the retardation in phase corresponds to an odd number of half-wavelengths (a half-wave plate) the ellipse will be again a line, but will make an angle $2A$ with the plane of vibration of the incident light. If the retardation corresponds to an odd number of quarter-wavelengths (quarter-wave plate) the emergent light will be elliptically polarized. If in addition A is 45 degrees, circularly-polarized light results.

LIGHT FILTER. A homogeneous optical medium that is characterized by its absorp-

tion in certain regions of the spectrum. A filter is used to change or control the total or relative energy distribution of a beam of light. In photography a filter may be placed over the light source or in some part of the optical path traversed by the light in reaching the photographic emulsion, generally over the camera lens.

LIGHT GAS GUN (MASS ACCELERATOR). A test apparatus using light gases instead of powder charges for propulsive energy. Projectiles at speeds starting at 10,000 mph and increasing to 20,000 mph may be obtained.

LIGHT MICROSECOND. The distance which light travels in one microsecond. This is a distance of 299.8 meters or 327.8 yards.

LIGHT, PLANE-POLARIZED. Light consists of electromagnetic waves with their electric and magnetic vectors constantly normal to the direction of propagation of the light. If the electric vectors of all components of a light-beam lie in the same fixed plane, the light is said to be plane-polarized.

LIGHT YEAR. In astronomy, a measure of distance equal to approximately 5.88 trillion miles. It is the distance traveled by light in a year.

LIGHTER-THAN-AIRCRAFT. Aircraft whose principal sustentation involves the displacement of air, as in a blimp or balloon.

LIGHTHOUSE TUBE. A vacuum tube used for high frequencies. Its technical name is the megatron. Its design minimizes the deleterious effects of interelectrode capacitance and lead inductance resonance effects.

LIGHTNING. The electrical condition of the earth's surface and of the atmosphere is quite different in stormy weather from its normal, fair-weather state. Over a level stretch of country in fine weather, there is distributed a negative surface charge estimated at about 0.00027 electrostatic unit per sq cm or 0.0014 coulomb per sq mile. Above this, the electric **potential** of the atmosphere increases with elevation at the rate of about 100 volts per meter, the upper atmosphere being, apparently, positively charged. The earth, the atmosphere, and the **ionosphere** thus form a vast **capacitor**, through the dielectric of which

there is constant leakage because of ionization. What maintains the charges against this leakage is not well understood.

LIGHTS. As navigational aids, the following types of lights are used: *Fixed*, a constant intensity beacon. *Intermittent*, a beacon alternately lighted and dark. *Flashing*, an intermittent beacon with the lighted interval shorter than the dark period. *Occulting*, an intermittent beacon in which the lighted interval is equal to or longer than the dark interval. *Blinker*, a beacon having more than 60 flashes per minute (i.e., one flash per second or more). *Undulating*, a beacon which varies rhythmically in intensity.

LIMIT CYCLE (SERVO). An oscillation of a servomechanism in which the maximum amplitude is reached and which continues at (usually) a fixed or varying frequency.

LIMIT LOAD. Load limit.

LIMIT LOAD FACTORS. In missile design, the maximum actual accelerations (in gravity units) anticipated during the life of the missile. Limit loads are obtained by multiplying the unit (one g) loads on the missile by the limit load factor.

LIMIT OF RESOLUTION (TELESCOPE). Using the Rayleigh criterion for the resolution of diffraction patterns, it can be shown that the limit of resolution of a telescope with circular aperture is given by

$$\theta = 1.220\lambda/a$$

where a is the diameter of the circular aperture, which limits the beam forming the primary image, λ is the wavelength of the light and θ is the minimum angle of resolution of the telescope.

LIMIT SWITCH. In mechanical or electromechanical equipment, an electrical contact (usually a microswitch) placed on one part of a device which is moving with respect to another, designed to interrupt the power and stop the relative motion of the parts. For example, limit switches are used on cranes to stop the motor before the mechanical limit of travel is reached or before the cable is nearly tight. They are primarily safety devices.

LIMITER. A circuit which limits the maximum positive or negative values of a wave

form to some predetermined amount. (It is used in frequency modulation systems to eliminate unwanted variations of amplitude in received waves.) It is essentially a rectifier. When limiting is not intentional, it is called "distortion." A diode type tube can be used for limiting. In two types of limiters, the orientation of the tube determines whether the circuit limits positively or negatively. A positive limiter clips off the positive portion of the signal, and a negative limiter clips off the negative swings of the signal. A triode can also be used to effect limiting, but if grid limiting is employed the output can only be negatively limited.

LINE FILTER. A filtering device used to prevent electrical disturbances, which may exist in the electrical service line, from entering a sensitive circuit, such as a radio receiver.

LINE HYDROPHONE. Hydrophone, line.

LINE, LOW-LOSS. A transmission line with small amounts of power dissipation per unit length.

LINE OF APSIDES. A line which contains the major axis of an ellipse is known as the line of apses of the ellipse. In astronomy the term is used to indicate the line joining perihelion and aphelion points on an orbit and extending to infinity to cut the celestial sphere.

LINE OF DEPARTURE. (LD) (1) The direction of a bullet or shell at the instant it clears the muzzle of the gun. (2) The direction of a bomb, rocket or missile at the instant of launching.

LINE OF NODES. The line of nodes is the astronomical term applied to line of intersection of any two fundamental planes. The line of nodes for the moon is the line of intersection of the plane containing the moon's orbit with the plane of the ecliptic. The line of nodes for any member of the solar system, other than satellites, is the line of intersection of the plane of the orbit of the object with the plane of the ecliptic. The line of nodes for the earth is the line of intersection of the plane of the earth's equator with the plane of the ecliptic.

LINE OF POSITION. In air navigation, a line on which an aircraft or spaceship is

known to be, i.e., a line containing all possible locations of an aircraft at a given instant. A line of position may be a circle of equal altitude, a radio bearing, a line in the direction of a bearing, etc. A railroad, highway, or the like may also provide a line of position.

LINE-OF-SIGHT. (1) The straight line between an observer's eye and a target or other observed object or spot, along which sight is taken. (2) The straight line between eye and target in gunnery, bombing, or rocket firing. (3) The straight line from a transmitting radar antenna in the direction of the beam, especially toward a target. (4) The straight line between a missile and its target.

LINE-OF-SIGHT COURSE. (1) A course in which the missile is guided so as to remain on the line joining the target and the point of control. (2) The distance to the horizon from an elevated point, including the effects of atmospheric refraction.

LINE-OF-SIGHT STABILIZATION. The stabilization of a radar antenna mounted on a ship or aircraft to compensate for roll and pitch, by means of changing the elevation angle of the antenna.

LINE SQUALL. An extremely turbulent, roll-type, squall cloud usually found at the leading edge of squall lines associated with rapidly moving cold fronts.

LINEAR ACCELERATOR. (1) A motion-producing test device which sets up a field of rapidly moving electromagnetic waves which carries a test projectile along at extreme speeds by induction. (2) A particle accelerator having its effective path, or most of its path, a straight line, and designed to produce high energy beams of positive ions. (3) A linear motion-producing test device, as a rocket-propelled sled on a track, upon which animals, humans or equipments can be subjected to programmed accelerations.

LINEAR ACTION. A term describing the dynamic behavior of a system in which the individual block elements which make up the whole system behave linearly over their operating ranges; thus they may be represented by systems of linear equations; e.g., a linear network is an electrical network in which the currents and voltages can be related by a set

of linear integro-differential equations with constant coefficients; these coefficients are functions of the parameters of the network.

LINEAR AMPLIFIER. (1) In electronics, a pulse amplifier in which the output pulse height is proportional to an input pulse height for a given pulse shape and up to a point at which the amplifier overloads. (2) Any amplifier in which the output signal is directly proportional to the input, within specified conditions.

LINEAR IMPULSE. Change in linear momentum. Linear impulse is expressed by:

$$Ft = m(v_f - v_i)$$

where Ft is the impulse (or force through time of acting, m is the mass, v_f is the final velocity, and v_i is the initial velocity.

LINEAR POWER AMPLIFIER. Amplifier, linear power.

LINEAR THRUST MISALIGNMENT. The distance from the thrust axis to the center of mass, in rockets in which the line of action of the thrust does not pass through the center of mass. (See also **angular thrust misalignment**.)

LINEAR TIME PLOT. A recording correlated with time showing the variation of a physical quantity (such as altitude of a missile) with all scales in linear measure.

LINEARIZATION. (1) In mathematics, an adjustment made to irregular functions to cause them to become linear functions. In most instances the term is not used rigorously, and means the process of smoothing a complex curve by joining average points into more or less a straight line. (2) In data reduction procedures (especially telemetry data reduction), the process of correcting raw data to remove all systematic errors. Systematic errors are corrected by calibration curves which are drawn by comparing known values to the indicated values from the measuring system. In telemetry linearization two calibration curves are applied to process the raw data. First to be used is the **end instrument** calibration curve, which is drawn on the ground before the missile flight by introducing known physical quantities to the pick-up device and noting its readings. Second to be used is

the calibration curve for the telemetry channel as obtained through readings made in flight. This is done during the missile flight by means of the inflight calibration technique common to most telemetry systems. In this technique, known voltages are generated in the missile during flight, and compared to the values indicated in the recovered signal as recorded on the ground. These two curves are then combined, and applied by means of an arbitrary function generator to correct the raw data readings. After such correction the data are said to be linearized although they may actually vary in a non-linear manner. (See also **calibration curve, data reduction, errors, inflight calibration and telemetry.**)

LIQUEFACTION. Transformation (phase change) to the liquid state; commonly, the change from the gaseous to the liquid state, particularly of substances that are gaseous at normal temperatures and pressures.

LIQUID OXYGEN. Oxygen in its liquid form. Liquid oxygen weighs 9.4 pounds per gallon and has a temperature of approximately -300°F , a boiling point of -297°F and a melting point (from solid to liquid) of -361°F . The density of liquid oxygen (LOX) at the boiling point is 1.14 gm/cm^3 . Liquid oxygen evaporates rapidly in unprotected surroundings, especially when being transferred from one container to another. Fueling a missile may cause a loss of as much as 7-10% of liquid oxygen by weight under the best conditions. Storage for any long period of time requires either a nearly perfect insulation and/or a form of refrigeration (usually a helium gas system). The best insulated tanks made can keep losses down to about $\frac{1}{4}\%$ per day.

Liquid oxygen is prepared from air by a process in which purified air is first liquefied and then separated into its two chief constituents, oxygen and nitrogen. These gases are easily separable by their different boiling points. Nitrogen and other gases boil off, leaving the oxygen. Liquid oxygen occupies about $1/800$ th the space occupied by gaseous oxygen at standard atmospheric conditions. Pure liquid oxygen is a bluish, somewhat magnetic, liquid. It can produce very severe burns, even in small quantities. Liquid oxygen tends to react violently with oil vapors, often causing them to burn spontaneously.

When liquid oxygen is used for missile fuels, care must be taken to insure that expansion joints between concrete slabs making up the pad area do not have bituminous materials for filler, or that other stray petroleum products do not provide an accidental hazard. Liquid oxygen is desirable for missile propellants, since it is the best oxidizing agent available. In spite of the many problems connected with its manufacture and handling, it is an excellent propellant. It boils when it comes into contact with metals at ordinary temperatures, requiring the filling lines to be of large diameter. Ordinary pumping speeds for liquid oxygen are 250-300 gallons per minute. Precooling of internal parts is necessary to prevent thermal shock effects. Liquid oxygen can be transferred by either gas pressure or pump (normally centrifugal pumps are used). Pumping rates of 750 gallons per minute are now used for missile fueling, with multiple pump units yielding filling rates of 1500 gallons per minute and more.

LIQUID PROPELLANT. A propellant in a liquid state used in rockets, as distinguished from a solid propellant.

Examples of liquid propellants include such fuels as alcohol, gasoline, aniline, liquid ammonia, and liquid hydrogen; oxidizers such as liquid oxygen, hydrogen peroxide (also applicable as a **monopropellant**), and nitric acid; additives such as water; and monopropellants such as nitromethane.

LIQUID PROPELLANT ROCKET ENGINE. Rocket engine, liquid propellant.

LIQUID ROCKET. A rocket using liquid fuel. (See **rocket engine, liquid propellant.**)

LISSAJOUS FIGURES. A characteristic and useful portrayal of the combination of two sine waves. Some typical Lissajous figures as appearing on an oscilloscope screen are shown in the diagram on Page 358. When the signals are out of phase they are oblique, tilted or otherwise at variance with the normal pattern. For example, a 1:1 ratio figure in phase is a circle, out of phase it is either an oblate or prolate ellipse at an acute angle to the vertical. Lissajous figures are used to analyze circuit performance, and to determine frequencies by comparison to a known standard.

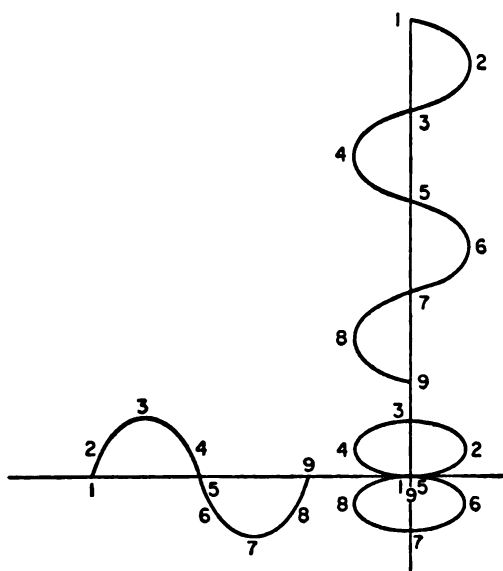


Diagram showing how Lissajous figures (lower right of diagram) are obtained—in this case from two simple harmonic motions at right angles.

LITHIUM. Metallic element. Symbol Li. Atomic Number 3.

LITHIUM HYDRIDE. The chemical compound of lithium and hydrogen (LiH). It has a boiling point of 2507°F, freezing point of 1256°F, and a specific gravity of 0.82. It has been considered as a possible rocket fuel.

LITHIUM STEARATE. A gelling compound of formula $(\text{LiCH}_3(\text{CH}_2)_{16}\text{CO}_2)$, sometimes employed with oils to solidify them for use in solid-propellant combinations.

LITHOSPHERE. The land portion of the earth's surface.

LITTLE JOE. The popular name for the U.S. Navy World War II, KAN-1 missile. It was a surface-to-air missile designed to combat the Kamikazi attacks.

LITTLE JOHN. A smaller version of the Honest John missile. The Little John was initiated in February, 1956, by the U.S. Army's Redstone Arsenal. The first prototype was fired in June, 1956. The missile was produced by the Douglas Aircraft Co. and the Emerson Electric Co. (as was Honest John). It was designed to have one-third the weight of Honest John. It was 12 feet in length and $12\frac{1}{2}$ inches in diameter (318 mm) and used a Hercules XM-47 solid rocket, with a preset type of guidance. It was designed for heli-

copter transportation. It was also called the M-31. (See missile, guided.) (See also illustration facing Page 251.)

LN. Liquid nitrogen.

LO. Local oscillator.

LOAD. (1) In aerodynamics, the downward force on an airframe or air surface member. Loading considerations are important in stress analysis to determine the possibility of failure under operating conditions. The most common loading considered is that of the wing. Wing loading is the gross weight of the aircraft divided by the wing area. (2) In electricity, the load is equal to the effective current multiplied by the effective voltage measured across the output terminals of a device supplying power. (3) In general engineering usage, the load on a machine or structure is the work which must be done by the machine, or the weight which must be carried by the structure.

LOAD, BASIC. In stress analysis, the load on a structural member or part of a missile in a condition of static equilibrium. When specific basic load is meant, the particular condition of equilibrium must be indicated.

LOAD CELLS. Strain gauges incorporated in the thrust mounts to weigh a missile as it is fueled, and to measure forces acting upon the missile when in vertical position in the test or launch stand. They are usually hydraulic cylinders of varying size depending upon the loads to be measured. A balanced piston bears against a current-carrying resistor whose resistance changes with load; thus the current is a measure of the load.

LOAD, DESIGN. In stress analysis, a specified load below which a structural member or part should not fail. It is the probable maximum applied load multiplied by the **factor of safety**. Also, in many cases, an appropriate basic load multiplied by a **design-load factor**.

LOAD FACTOR. In stress analysis, the ratio of the force acting on a mass to the weight of the mass. The net external force on the mass may be expressed in terms of gravity units. *Limit Load Factor* is the maximum value of gravity units expected during the life of the missile.

LOAD FACTOR, ULTIMATE STRENGTH. The load factor which shall cause the ultimate strength to be reached.

LOAD FACTOR, YIELD STRENGTH. The load factor which will cause the yield strength to be reached.

LOAD, ULTIMATE. In stress analysis, the maximum load a structure will support without failure. (The ratio of ultimate and limit loads is the **factor of safety**.)

LOAD, WORKING. In stress analysis, the load at which a structure works. Usually, but not always, the design load.

LOADING COIL. (1) An inductance inserted at regular intervals along a long transmission line or cable to increase the line's characteristic impedance and reduce its attenuation constant. (2) An inductance inserted in series with an antenna to increase its electrical length.

LOADS REPORT. A standard report used in missile design, which includes the basic transportation, storage, stowage, handling, environmental, launcher, boost, flight and recovery loads; spanwise and chordwise pressure distributions on all important elements; inertia and gust loads for all important flight phases; pressure vessel loads; rotary and longitudinal acceleration factors, etc. Special and conventional design methods and techniques on which the design is based should be included.

LOBE. One of the three-dimensional portions of the radiation pattern of a directional antenna. The principal lobe having the greatest intensity and directivity is called the beam. A typical antenna especially designed for high directivity has several side lobes of much shorter range, lesser strength, and more fan-like in shape than the main lobe. In a general sense the lobe refers to the general energy pattern emitted, eliminating from consideration any side radiations. Thus, one might speak of the lobe being "fan-shaped" in reference to the principal lobe only.

LOBE, MAJOR (BEAM). The radiation lobe containing the direction of maximum radiation.

LOBE, SIDE. A portion of the radiation from an antenna outside the main lobe

(beam) and usually of much smaller intensity. A side lobe is a region between two minima in the pattern.

LOBE SWITCHING. A form of scanning in which the direction of maximum radiation is switched periodically through two or more directions.

LOCAL APPARENT TIME. (1) Apparent time measured with reference to a local meridian. (2) In celestial navigation, the apparent time of the observer's meridian.

LOCAL CONTROL. Control, local.

LOCAL HOUR ANGLE. The angle between the hour circle passing through the observer's position and the hour circle through a given celestial body, measured westward through 360°.

LOCAL MACH NUMBER. The Mach number at some specified point on a moving body, as distinguished from the remote Mach number.

LOCAL MEAN TIME. (1) Mean time measured with reference to any particular meridian. (2) In celestial navigation, the mean time of the observer's meridian.

LOCAL OSCILLATOR. (1) An electronic device for generation of a reference frequency. It may be of the usual low-frequency, negative-grid type with the tuning circuits consisting of coaxial elements; or, more often, velocity modulation tubes are used. (The latter type is practically the only suitable oscillator for receiver use above 4000 mc per sec.) (2) The oscillator in a superheterodyne receiver which supplies the frequency to the mixer necessary to heterodyne the original signal frequency down to the desired intermediate frequency. The elements for this oscillator may be in the same tube envelope as the mixer.

LOCAL SIDEREAL TIME. (1) The time of the sidereal day, measured with reference to any particular meridian. (2) In celestial navigation, the time of the sidereal day with reference to the observer's meridian.

LOCALIZATION. The identification of the apparent direction of a sound source by means of binaural effects.

LOCK-ON. The instant at which a **radar** is enabled automatically to track its target.

LOCK-ON RANGE. The range from a **radar** to its target at **lock-on**.

LOGARITHMIC AMPLIFIER. An amplifier whose output signal is a logarithmic function of the input signal.

LOGARITHMIC DECREMENT. The natural logarithm of the ratio of two successive amplitudes of a decaying signal or motion. This quantity is useful in determining the amount of damping in a system by measuring the rate of decay of **oscillation**. (See also **damping**, **critical**.)

LOGICAL DESIGN. A computer design discipline in which the computational features and elements are logically grouped to provide an entity capable of handling a group of data or to make a particular calculation.

LOGISTICS. The functions of supply and transport in support of the military establishment; i.e., those aspects of military operations that deal with: (a) design and development, acquisition, storage, movement, distribution, maintenance, evacuation and disposition of materiel; (b) movement, evacuation and hospitalization of personnel; (c) acquisition or construction, maintenance, operation, and disposition of facilities; and (d) acquisition or furnishing of services. It comprises both planning (including determination of requirements) and implementation.

LOGISTICS CONCEPT. A general statement of approved military policy on logistics for a specified weapon system. The logistics concept establishes the overall logistics policies, objectives, assumptions and requirements for the particular weapon system, based upon the weapon system requirements presented in the operations concept.

LOGISTIC(S) PLAN. The logistic plan is based on the operations concept, operations plan, and guidance contained in the logistics concept. It includes a general description of the materiel support system and specific guidance to the using commands and subordinate command activities on actions to be taken and methods of supporting the weapon system.

LOGISTIC(S) PROTECTION. In a guided missile system, that provision that insures

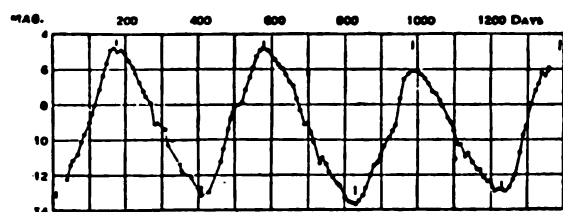
the missile against functional degradation due to all the environmental factors encountered from the manufacturer's plant to operational expenditure. This environmental phase may be divided into two categories: (a) Transportation: Any movement, vertical or horizontal, of the missile. (b) Storage: The time during which the missile is not being moved, and may be of short or extended duration.

LOKI. A small solid-propellant rocket, originally developed for antiaircraft use, but later applied to many development uses where a small high velocity vehicle is desired. These rockets have been used in clusters for increased thrust from multiple assemblies. The effective altitude of a LOKI as an antiaircraft (surface-to-air) rocket was approximately 12 miles. It was fin stabilized and unguided. Its size was approximately 3 feet long and several inches in diameter. The 224B-1 LOKI had approximately 0.8 seconds burning time. It was developed immediately following World War II (from the German Taifun rocket), but was never used in service.

LOKTAL BASE. In electronics, a base or socket especially designed for small vacuum tubes which locks the tube into an eight pin ("loktal") socket. The tube pins are sealed in the glass envelope in the loktal base design, which is standard throughout the industry.

LONG-PERIOD VARIABLES. Examination of the curve appearing in the article on **variable stars**, indicates that there is a considerable group of variables with periods greater than 100 days. This group of objects is known as the long-period variables. More than half of the long-period variables have periods between 250 and 400 days. The accompanying figure (Light curve of the long period variable χ Cygni) shows the **light curve** of a long period variable. Examination of the diagram indicates at once that the characteristics of variation do not repeat themselves exactly from cycle to cycle. This irregularity in the shape of the light curve from cycle to cycle is characteristic of all long-period variables. All of the long-period variables are red stars, most of them being **M spectral class**, with a few in the N, R, and S classes.

There is no adequate explanation for the variability of the long-period variables. The pulsation theory, as discussed for the **Cepheid**



Light curve of the long period variable χ Cygni. (From observations, during the years 1922 to 1925, by the American Association of Variable Star Observers.)

variables has many attractive features, but on the basis of this theory we should expect the stars to be hottest when they are of smallest diameter and this is exactly contrary to the observed diameters of Mira. The similarity between the forms of the light curves of certain long-period variables and the sun-spot curve has frequently been commented upon, and the statement is sometimes made that our sun is a long-period variable with period of about 11 years. However, the period is much longer than any known long-period variable and, furthermore, the sun is a G-type star, so it seems that variability in the sun and in long-period variables must be totally different phenomena.

LONG PLAYING ROCKET. A temporary orbital vehicle. It is abbreviated LPR and refers to a satellite type vehicle having a long but finite estimated orbital life.

LONG-RANGE. Of a missile, having a range longer than 1500 miles.

LONG RANGE PROVING GROUND. Obsolete name for the Air Force Missile Test Center (or Florida Missile Test Range) at Patrick Air Force Base (Cocoa Beach), Florida, now the Atlantic Missile Range.

LONG WAVE. In radio, any wave longer than 100 meters. Long waves comprise all the low frequency bands below 3 mc/s and include all of the standard broadcast bands. (See **frequency bands**, **microwave** and **short wave**.)

LONGERON. In structural design, an element used to carry drag or compressive loads; also used to "break up" sheet panels to provide increased rigidity and load carrying capacity. Typical use: semi-monocoque construction of missile airframes.

LONGITUDE. Angular distance east or west of the prime meridian of the earth, which is an imaginary line on the surface made by intersection with it of a plane passing through the poles (i.e., a meridian), and Greenwich, England. Longitude is measured either in hours and minutes, or from 0 through 360 degrees.

LONGITUDINAL. Of or pertaining to the length or the lengthwise attitude or action of a missile or space craft.

LONGITUDINAL FORCE COEFFICIENT. The resultant force coefficient produced by resolving all aerodynamic forces into their composite resultant in the longitudinal direction (i.e., along the wind direction). The longitudinal force coefficient is defined as:

$$C_x = C_D \cos \alpha - C_L \sin \alpha$$

where C_D and C_L are the coefficients of **drag** and **lift**, and α is the angle of attack. (See also **coefficient of force** and **normal force coefficient**.)

LONGITUDINAL STABILITY. Stability, longitudinal.

LONGITUDINAL WAVE. A wave in which the direction of displacement at each point of the medium is the same as the direction of propagation. The individual particles move in the same direction as the direction of propagation of the wave; the particle motion is normal to that of a **transverse wave**.

LOON. The U.S. Navy's popular name for the KUW-1, or American copy of the German V-1 missile. The Loon weighed 4730 pounds (less RATO boosters), carried 1900 pounds of explosive and 1000 pounds of fuel. The overall length was 25½ feet, fuselage diameter 32 inches, and wing span, 19 feet. The maximum range was 150 miles. Operating altitude was planned to be 4000 feet. Propulsion was by a Ford-Schmidt pulsejet. Guidance was radio command. (See **JB-2**.)

LOOP. A series of interconnected components, accessories, assemblies or subassemblies required to complete a specific function such as tracking, temperature control, antenna positioning, synchronizing, pressure control, etc., within a system.

LOOP ANTENNA. An antenna in the form of a circle or other closed figure used for its directive characteristics. When the loop is broadside to a signal source, reception is at a minimum (nulled), when the edge faces the incoming signal, it is at a maximum.

LOOP GAIN. In feedback terminology, the gain around the feedback loop, numerically equal to the product of the forward gain by the gain of the feedback network.

LOP-GAP. A British missile developed soon after World War II. It was a liquid-propellant type burning methyl alcohol (mixed with water) oxidized by liquid oxygen. Fuel flow was induced by pressure of a slow-burning powder cartridge placed in a space between both fuel tanks. The motor burned at 1000 pounds thrust for 25 seconds to give maximum velocity of Mach 1.4. Take-off was **RATO**, using 7 bottles in a cluster around the missile. These provided a 1700 foot per second velocity after their burning time of 4 seconds. The missile was 14 feet in length and 9½ inches in diameter. It was used in 1948 for surface-to-air research.

LORAN. A long-range, pulsed, hyperbolic radio aid to navigation used by ships, airplanes, etc. The name is a composite of *Long Range Air Navigation*. Position lines are determined by the measurement of the difference in the time of arrival of synchronized pulses. The system requires the use of a master transmitting station and one or more slave stations. The master and slaves are separated by several hundred miles or more, so as to form a broad-base pattern. The arrival of a pulsed signal from the master station at the slave stations triggers each slave transmitter, which then also transmits a pulse. The shipborne installation compares the times of receipt of two pulses, one from the master and one from a slave station. The time difference determines a line of position, hyperbolic in shape, upon which the vehicle must lie. The same determination with the master station and another slave station establishes another hyperbola. The point of intersection of the two hyperbolas is the position of the ship. (See also **DECCA**, **GEE** and **SHORAN**.)

LORAN-C. A **LORAN** system developed by the Sperry Gyroscope Co. and used by the

U.S. Navy. It employs a 100 kilocycles per second signal in order to permit use of the ground wave. By gating out the sky wave and matching cycles within the radio frequency pulse, it is possible to achieve high accuracy, limited principally by propagation anomalies.

LOSS (TRANSMISSION LOSS). A general term used to denote a decrease in signal power in transmission from one point to another. Loss is usually expressed in **decibels**.

LOSS, INSERTION. Insertion loss.

"LOSSY." An adjective applied to a dielectric material which dissipates energy.

LOUDSPEAKER (SPEAKER). An electro-acoustic transducer (see **transducer**, **electro-acoustic**) usually intended to radiate acoustic power effectively at a distance in air.

LOW. (1) An area or region of low atmospheric pressure. (2) A cyclone. (3) A depression or trough in a constant-pressure surface.

LOW FREQUENCY. In radio, frequencies between 30-300 kc/s. The abbreviation is **LF**. (See **frequency bands**.)

LOW-FREQUENCY LORAN. A modification of standard **loran**, operating in a low-frequency range of approximately 100-200 kilocycles to increase range over land and during daytime. Often called "LF **loran**." The **LORAN-C** system, as developed by the Sperry Gyroscope Co. is such a system.

LOW-ORDER DETONATION. Detonation.

LOW-PASS FILTER. Filter, low-pass.

LOW-PRESSURE AREA. An area of low atmospheric pressure.

LOW-PRESSURE OXYGEN EQUIPMENT. A type of aircraft oxygen equipment designed to function at a relatively low internal gas pressure. Low-pressure oxygen equipment is made to withstand up to 450 pounds pressure per square inch, and will function at a pressure as low as 50 pounds.

LOX. The commonly accepted abbreviation for liquid oxygen. The term originally denoted liquid oxygen explosives (i.e., *L* is

liquid, *O* is oxygen, and *X* is explosive), but this usage is no longer observed. Liquid oxygen is explosive with easily oxidizable materials, while mixtures of it with organic materials can be detonated by shock. Gaseous oxygen is often abbreviated GOX.

LOXING TIME. The time needed to pump the required amount of liquid oxygen into a missile lox tank or tanks and to reach a state of launch readiness.

LOXODROMIC CURVE. In cartography, a **rhumb** line which spirals toward the poles.

LOZ. Liquid ozone.

LRPGD. Long Range Proving Ground Division.

LTV. Launch test vehicle.

Lu. Lutetium.

LUG BAND. Any of the bands on an aircraft rocket which, with the appropriate fittings, attaches the rocket to a rail-type or post-type aircraft rocket launcher.

LULU. A U.S. Navy air-to-underwater nuclear warhead missile (announced, 1956).

LUMEN. The unit of **luminous flux**. It is equal to the flux through a unit solid angle (steradian) from a uniform point source of one **candle**; or to the flux on a unit surface all points of which are at unit distance from a uniform point source of one **candle**.

LUMINANCE. The quantitative attribute of light that correlates with the sensation of **brightness** and is the evaluation of radiance by means of the standard **luminosity function**. Units fall into two classes, (1) "intensity-luminance" defined by $B' = I/(A \cos \theta)$ where I is the luminous intensity of the area A as viewed along a direction that makes an angle θ to the normal to the surface, and is measured in candles/meter², candles/ft², candles/cm², and a second set of units, (2) "lambert-luminance," where $B' = \pi B$, and is measured in meter-lamberts, ft-lamberts, cm-lamberts, etc.

LUMINESCENCE. Broadly, this term refers to the emission of light due to any other cause than high temperature. A firefly, for example, as well as certain fungi and many

marine forms exhibit bioluminescence. Some electrolytic rectifiers are sources of **galvanoluminescence**. **Triboluminescence** is observed upon vigorously grinding certain solids, notably ordinary sugar. **Thermal luminescence** is shown by certain substances such as diamond, marble and fluorite which emit light at temperatures below a red heat. **Photoluminescence** is the emission of light as a result of nonluminous radiations.

A large variety of substances become luminescent when stimulated or "excited" by suitable radiation or by emissions such as **cathode rays** or **β -rays**. This phenomenon is apparently quite complex and is exhibited in various aspects. In some cases the light is emitted only so long as the exciting emission is maintained; it is called **fluorescence**. The screen of a fluoroscope thus responds to x-rays. In other cases the luminescence persists after the excitation is removed and it is then called **phosphorescence**. Thus zinc sulfide, under certain conditions, glows brightly for a time after exposure to daylight or lamplight, but the luminosity decays rapidly and disappears, usually within a few minutes. Some materials exhibit **thermoluminescence**; that is, they become luminescent, after exposure to excitation, upon being raised to a sufficiently high temperature. Resonance radiation may be regarded as a type of fluorescence in certain gases.

Stokes pointed out that when luminescence is excited by radiation, the frequency of the luminescence is usually less than that of the incident radiation. This is of course always true when visible luminescence is excited by ultraviolet rays, x-rays, or γ -rays.

Numerous theories regarding luminescence have been proposed. They agree mostly in assuming that the emission of luminescence is due to the removal of electrons from molecules by the energy of the exciting rays, and the release of part of all of the energy upon their return. The quantum theory of radiation and electronic processes has done much in recent years to clarify certain aspects of the phenomena.

LUMINOSITY. (1) In photometry, the luminous efficiency of a light source. **Luminosity** can be expressed as the total luminous efficiency (K) or as the monochromatic luminous efficiency (K_λ). (2) In astronomy, the luminosity of a star is its intrinsic bright-

ness either in absolute magnitude or relative to the sun.

LUMINOSITY FACTOR. In photometry, the ratio of the luminous flux at that wavelength to the corresponding radiant flux. It is expressed in lumens per watt.

LUMINOSITY FUNCTION (STANDARD).

Because of the variable sensitivity of the eye to radiation of different wavelengths, a standard function has been established by the Commission Internationale de l'Éclairage (CIE), formerly called in English translations International Commission on Illumination (ICI), for converting radiant energy into luminous (i.e., visible) energy.

For the standard conditions chosen in establishing this standard luminosity function (photopic vision) the luminously effective radiant intensity in lumens of radiation of spectral intensity J_λ watts/unit wavelength is given by

$$680 \int_{\lambda=0}^{\lambda=\infty} y_\lambda J_\lambda d\lambda$$

where y_λ is the standard luminosity function normalized to a value of unity at 555 millimicrons. The numerical values for y_λ are commonly given as a luminosity curve.

For very low levels of intensity (scotopic vision) the peak of the luminosity function curve shifts toward the violet for young eyes (507 m_μ) with an absolute value of 1746 lumens/watt.

LUMINOUS INTENSITY. In photometry, the solid angular flux density in a given direction. It is the luminous flux on a small surface normal to the direction in question divided by the solid angle in steradians which the surface subtends at the source of light. That is:

$$I = dF/d\omega$$

LUMPED CONSTANT ELEMENTS. Distinct electrical equipments, small compared to a wavelength, which are calibrated and used in the control of voltage and current, and employed in conjunction with other electrical-electronic equipment.

LUNAR DISTANCE. For a determination of terrestrial longitude the Greenwich time must be known. Prior to the invention of chronometers and the subsequent develop-

ment of radio broadcasting of time, the determination of Greenwich time at sea was very complicated. For many centuries it was realized that the position of the moon relative to the stars might be considered as a clock hand.

Up to 1912 the American *Ephemeris*, and corresponding publications of other nations, published the distance of the center of the moon from the center of the sun, the four brighter planets, and certain bright stars, for every three hours of Greenwich time. Only those objects were used which were within convenient distance of the moon at the given time. All that was necessary for a navigator to determine his Greenwich time at any instant was to measure with his sextant the distance between the bright limb of the moon and a tabulated "lunar distance star." Then, after applying necessary corrections, by interpolation from the tables he could find the Greenwich time corresponding to the instant of observation.

While this problem is fundamentally very simple in theory, in practice the method will not yield very accurate results.

LUNAR PROBE. An instrumental (or manned) space vehicle which operates near or on the moon. (See table in definition of **instrumental vehicles for space research**.) (See also **Pioneer** and **Thor Able**.)

LUNAR SATELLITE. A lunar probe designed to enter an orbit about the moon at a distance of approximately 500 nautical miles from the lunar surface. The satellite's orbit can be expected to be elliptic for reasons of practical limitations of guidance accuracy, and because of terrestrial perturbations. The perturbation of a circumlunar elliptic orbit with an apogee distance of three lunar radii is about the same as a lunar perturbation of a circumterrestrial elliptical orbit with 12.2 earth radii (or about 40 lunar radii) apogee distance.

The desirable distance from the moon will depend on the mission of the lunar satellite. For instance, one application would be to gain more definite information about the true shape of the moon. One could attempt to measure the perturbations of the circumlunar orbit, thus the deviation of the moon's shape from a true sphere would reveal itself. It appears that these deviations are small, much smaller than the corresponding deviations of

the earth's shape. Therefore, the lunar perturbation will be small also. In order to obtain a measurable effect and eliminate as much as possible the interference from terrestrial perturbation, very close proximity to the moon is required. Fortunately, there is no atmosphere to speak of which could interfere with such a close orbit.

One of the most intriguing applications of the lunar or appropriately launched cislunar satellites is, of course, the exploration of the lunar surface proper. This can be done in several ways: by optical observation, by radiation "ferreting" to investigate the possibility of radiation sources on the moon's surface, by producing a gas-blast artificial "wind" near the surface to determine the consistency of the lunar soil, by exploding bombs on the surface and finally, by controlled landing and re-ascent of lunar satellites.

LUNAR SPACE. Space, lunar.

LUNEBERG LENS. An artificial type of lens employed at microwave frequencies for focusing to attain high gain.

LUTECIUM. Rare earth metallic element. Symbol Lu. Atomic number 71.

LUX. The M.K.S. unit of illuminance, equal to one lumen meter⁻².

LW. Late warning.

LYMAN ALPHA REGION. In solar spectroscopy, the far ultraviolet region of the spectrum of the hydrogen atom (around 1000 Å). It is a principal spectral region of the Sun's light and is the particular subject of many upper atmospheric and satellite measurements.

LYRA. (The harp.) This constellation, while small in size, contains a number of most interesting objects for an observer with a telescope, whether the instrument be large or small. The constellation is most easily distinguished by the equilateral triangle with the star Vega at one of its apexes.

LYRIDS. The Lyrids are meteor showers which are observed about April 20 of each year. The orbit of the radiant point was definitely associated with the orbit of comet 1861 I. by Weiss.

A few scattered members of this shower are observed coming from the radiant point in the constellation of Lyra every year, but there has not been any very striking display since 1803. Since there have been striking showers in the past, the assumption is made that there is a large swarm of meteors at some undetermined point along the orbit, and that we may be treated to another brilliant display during some April in the future.

M

M. (1) Meter (m). (2) Mass (m or M). (3) Mass of molecules or atom (m or m_m). (4) Mass of electron (m_e). (5) Mass (rest) (m_0). (6) Modulation factor (m). (7) Molecular weight (M). (8) Direction cosine (l, m, n). (9) Mesh (m or M). (10) Slope of equilibrium curve (m). (11) Metal (M). (12) One-thousandth (m). (13) Strength of magnetic pole (m , but p is preferred). (14) Magnetization or intensity of magnetization (M). (15) Magnetic moment (m). (16) Minute (m). (17) Mach number (M). (18) Molecular weight (M). (19) Mole (M). (20) Moment of force (M). (21) Pitching moment (aerodynamics) (M).

M-3. The Nike missile sustainer motor fuel (UDMH/JP-4).

M-8. Rocket, 4.5 inch.

M-31. Honest John.

M-47. Little John.

Ma. Milliampere.

MACE (TM-76A). A United States Air Force surface-to-surface missile first launched on June 10, 1958, at the Holloman Air Force Missile Test Center. This test launching was completely successful in its objective, which was to demonstrate the recoverability of the missile in training through a new system involving a series of parachute openings in flight. It was then destroyed by range safety procedures. This missile may carry a nuclear or conventional warhead. It has a speed of over 650 m.p.h.; a ceiling over 40,000 ft.; and a range over 500 nautical miles. It has a length of 44 ft.; a span of 22 ft. 10 in.; and a self-contained navigation system. It is ground-launched, with a booster giving a total thrust over 100,000 lb.

The guidance in the B model is all-inertial. It is powered by an Allison J-33-37 turbojet. Contractors are the Glenn Martin Co., Good-year Aircraft and AC Spark Plug. It has

been developed as a successor to **Matador**. (See **missile, guided**.)

MACH. A unit of speed equal to the velocity of sound in the given medium.

MACH ANGLE. The angle between a Mach line and the path of a body moving with supersonic speed. The sine of this angle is the ratio of the local speed of sound to the missile velocity.

MACH CONE. A hypothetical conical surface having at its apex a point source moving with supersonic speed, so that all of the shock disturbances remain inside the surface. Outside of the Mach cone the fluid is unaffected by the motion of the moving body. The Mach cone is bounded by a weak shock wave and a line drawn on the Mach cone from the vertex is known as a **Mach line**.

MACH DIAMOND. A series of spaced, light areas in rocket exhausts caused by local equilibrium shifts.

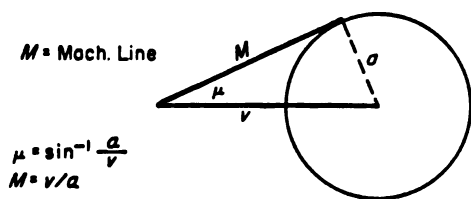
MACH EFFECT. A single effect, or a total effect, resulting from objects moving at transonic or supersonic speeds. (See **Mach intersection**.)

MACH FAN. In supersonic aerodynamics, an **expansion fan**.

MACH FRONT. **Mach stem**.

MACH INTERSECTION. The intersection of two **Mach waves**, especially at those points at which an increase of pressure is produced.

MACH LINE. An imaginary line drawn at an angle to the path of a rapidly moving body. It represents theoretically the shock wave which would be produced by a microscopic point moving with the speed of the body. The angles of very weak shock waves closely approximate the angle of the Mach line. Geometrically, the Mach line is determined as indicated in the figure on Page 367, which also shows a **Mach triangle** **Mav**.



Mach line.

MACH METER. An instrument for measuring and indicating the **Mach number** of a missile in flight. (This parameter is often used to adjust the gain of the control system or engine thrust.) It is also called a Mach indicator.

MACH NEEDLE. A special needle or pointer on the Mach indicator of a high-speed airplane which can be preset to indicate when the airplane is approaching the speed of its **critical Mach number**.

MACH NUMBER. The ratio of the speed of a traveling body to the speed of sound in the medium traversed. The speed of sound varies from about 750 mph at sea level to around 650 mph at very high altitudes, varying somewhat with air temperature. Mach number is given by the relationship:

$$M = v/c = \frac{v}{\sqrt{gRT}}$$

where M is the Mach number, v is the velocity of the traveling body, c is the velocity of sound, g is the gravitational acceleration, R is the gas constant, and T is the absolute temperature.

MACH STEM. A shock wave or front formed above the surface of the earth by the fusion of direct and reflected **shock waves** resulting from an air-burst nuclear weapon.

MACH TRIANGLE. Mach line.

MACH WAVE. (1) A **shock wave** theoretically occurring along a common line of intersection of all the pressure disturbances emanating from an infinitesimally small particle moving at supersonic speed through a fluid medium; such a wave is considered to exert no changes in the condition of the fluid passing through it. The concept of the Mach wave is used in defining and studying the realm of certain disturbances in a supersonic field of flow. (2) A very weak shock wave

appearing, e.g., at the nose of a very sharp body, where the fluid undergoes no substantial change in direction.

MACHINE. A contrivance of some sort; in aeronautics, a contrivance, device, or structure intended to travel, glide, soar, or float in or through the air, or above the earth; a flying machine; an aircraft.

This term is applied to all aircraft, including balloons, airships, gliders, airplanes (including rotary-wing airplanes), and experimental flying models, and is also applied, though infrequently, to guided missiles and the like; this last usage, though rare, illustrates the need and search for an inclusive term for aircraft, rocket vehicles, and similar "machines."

MAD AEC. Military Application Division of the Atomic Energy Commission.

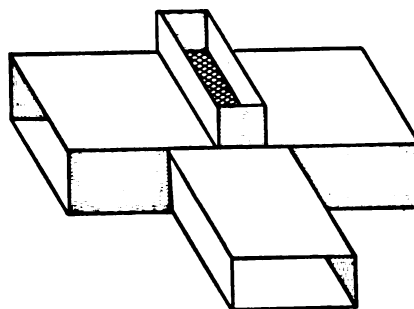
MADAM. An automatic film reader and analog computer for **telemetry** data reduction.

MADW. Military Air Defense Warning (Net).

MAE. Mean absolute error.

MAGAMP. Magnetic amplifier.

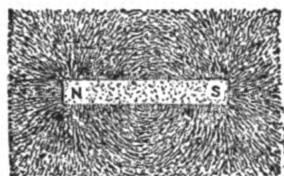
MAGIC TEE. In microwave techniques, a particular radar wave-guide configuration, so-called because its physical aspect resembles a double letter "T." The use of this configuration permits the coupling of a radar transmitter and receiver to a common antenna without the use of a **T-R (Transmit-Receive)** unit. (See figure.)



Magic tee waveguide junction.

MAGNAFLUX TESTING. A method of inspection used to locate cracks, cavities or seams in steel parts at or very close to the

surface. Special equipment has been developed for this test and several methods are used. In principle, the part is magnetized and magnetic powder is applied, wet or dry. This powder adheres to the surface in characteristic patterns when flaws are present in the metal. Interpretation of these patterns is complicated by a number of variables which affect the local magnetic fields, and so experience is necessary to judge the patterns correctly.



Graphical magnetic field of a bar magnet.

MAGNESIUM. Metallic element. Symbol Mg. Atomic number 12.

MAGNET. In ancient times it was known that stones containing magnetite had qualities which were not the property of other stones. It was found that they would attract iron, and when freely supported would turn so that their axis would take a north-south direction. These lodestones were the earliest magnets, but now are natural curiosities only, since the magnets used in compasses, instruments, magnetos, and all the various array of equipment which embodies a magnetic field produced by a magnet, are artificially constructed of hardened steel, magnetized by a strong magnetic flux. This type of magnet may be said to be a permanent magnet, in contrast to the **electromagnet**.

A magnet is a body possessing the property of attracting magnetic substances. The so-called permanent magnet should be used where a constant magnetic field is to be produced, since a well-made permanent magnet loses its magnetism very slowly, and then only up to a certain point, after which it is said to be aged. Thereafter it maintains a constant degree of magnetism unless subjected to strong de-magnetizing effects. Manufacturers of permanent magnets for precision instruments artificially age them during the process of manufacture. A bar which has been magnetized is found to have poles. These are centers where magnetic attraction is strongest. If the magnet is free to turn,

the pole which points northerly is called a north pole, and the other a south pole. Like poles repel each other with a magnetic force, and unlike poles attract each other. The earth is a large magnet having magnetic poles somewhere near, but not coincident with, the geographic poles. Since unlike poles attract each other, and the north pole of a magnet is taken as that which points northerly, it is the earth's south magnetic pole which lies near the north geographic pole. A magnet, delicately made, and freely suspended, becomes a **compass**.

MAGNETIC AMPLIFIER. Amplifier, magnetic.

MAGNETIC BEARING. A direction for which the reference line is magnetic north.

MAGNETIC BRAKE. A friction brake applied by means of an electromagnet (solenoid).

MAGNETIC COMPASS. Any compass in which the sensing element, as a magnetic needle or compass card, aligns itself with the direction of the horizontal component of the earth's magnetic field, including the gyro flux-gate and the gyrosyn compasses.

MAGNETIC DAMPING. Lenz' law.

MAGNETIC DIPOLE. A convenient fiction for describing the first order properties of **magnetic moment**. The dipole is conceived as two closely-spaced magnetic poles of opposite sign, but equal strength.

MAGNETIC DRAG. The retarding force exerted by a **magnetic field**, specifically that of the earth.

MAGNETIC EQUATOR. Isoclinic lines.

MAGNETIC FIELD. A vector-function field described by the **magnetic induction** (**B**). The term magnetic field is used interchangeably to refer to induction (**B**) and magnetizing force (**H**).

MAGNETIC FIELD, EARTH. Earth magnetic field.

MAGNETIC FLIP-FLOP. A bistable circuit employing one or more **magnetic amplifiers** so arranged as to have two discrete levels of output which may be obtained by adjusting the control voltage or current.

MAGNETIC FLUX. The magnetic flux through any closed figure, such as a circle, a rectangle, or a loop of wire, is the product of the area of the figure by the average component of **magnetic induction** normal to that area. Specifically,

$$\phi = \int \mathbf{B} \cdot d\mathbf{s}.$$

Thus, if a rectangle 5 cm × 8 cm is placed in a region where there is a uniform magnetic induction of 2500 gauss, and at an angle of 30° with the lines of induction, the magnetic flux through it is 2500 gauss × 40 cm² × sin 30° = 50,000 gauss-cm² or "maxwells." The magnitude of this quantity is often conventionally represented by imagining the lines of induction to be so spaced that the number of them through a given area is equal to the number of gauss-cm² or maxwells of flux through that area. The flux in the above example would be commonly expressed as 50,000 "lines." When a coil has several (*n*) turns and each turn has approximately the same flux (ϕ) through it, the effect is the same as for a single loop with the flux $n\phi$ through it. This product, which is called "linkage," is expressed in "maxwell-turns" or "line-turns." The magnetic flux or the linkage through a loop or a coil may be measured by putting into the circuit a ballistic (undamped) galvanometer and then suddenly removing the flux (or the coil). If the resistance of the whole circuit and the constant of the galvanometer are known, the flux may be calculated from the "throw" of the galvanometer.

MAGNETIC HEADING. A heading for which the direction of the reference line is magnetic north.

MAGNETIC INCLINATION. Dip.

MAGNETIC INDUCTION (*B*) (MAGNETIC FLUX DENSITY). Magnetic induction is the basic observable property of a **magnetic field**. It is directly associated with the force on a current element or the electromotive force induced in a moving conductor. The mechanical force on a length *d**l* of a circuit carrying a current *I* is given by

$$d\mathbf{F} = I d\mathbf{l} \times \mathbf{B}.$$

The electromotive force induced in a conduc-

tor of length *d**l* moving with a velocity *v* is given by

$$dE = \mathbf{B} \times \mathbf{v} \cdot d\mathbf{l}.$$

MAGNETIC LENS. An arrangement of coils, electromagnets, or magnets so disposed that the resulting magnetic fields produce a focusing force on a beam of charged particles.

MAGNETIC MERIDIAN. Any line representing the horizontal component of the **earth magnetic field** that passes through the magnetic poles.

MAGNETIC MEMORY. A bistable magnetic device employed to store information. The simplest and probably most common example is simply a **core** made from a magnetic material such as Deltamax which possesses a nearly rectangular **hysteresis loop** (*B_r/B_s* → 1). It is thus capable of "remembering" indefinitely whether or not it has been magnetized.

MAGNETIC MOMENT. The magnetic moment of a current loop or a magnetized body is a measure of the magnetizing force (**H**) produced by the current or magnetized body. The magnetic moment of a plane current loop is a vector (**m**), normal to the plane of the loop and directed so that the current has a clockwise rotation around **m**. The magnitude of **m** is the product of the current and loop area. The magnetic moment of a magnetized body is the vector summation of the magnetic moments of the internal current loops and spins of the body. The magnetizing force produced at a displacement **r** from a small source of moment **m**

$$\mathbf{H} = -\nabla \frac{\mathbf{m} \cdot \mathbf{r}}{r^3}.$$

(See also **dipole moment**.)

MAGNETIC NORTH. The direction indicated by the north-seeking element of a magnetic compass when influenced only by the **earth magnetic field**.

MAGNETIC RECORDER. Equipment incorporating an electromagnetic **transducer** and means for moving a ferromagnetic recording medium relative to the transducer for recording electric signals as magnetic variations in the medium. However, the generic term "magnetic recorder" can also be applied to an instrument which has not only facilities

for recording electric signals as magnetic variations, but also for converting such magnetic variations back into electric variations.

MAGNETIC TAPE. (1) A means for storing information by varying the magnetic properties of a moving tape. (2) Tape impregnated with a ferromagnetic substance which undergoes varying magnetization corresponding to the magnitude of an applied alternating current.

MAGNETIC TESTING. A nondestructive means for testing ferromagnetic materials to determine variations in the physical and chemical properties, stress concentrations, structures, etc. In general, the tests are used to determine defects such as cracks, seams, voids or inclusions, and consist of passing an electric current (a-c or d-c) through the part to create a magnetic field about the part, or through a coil surrounding the part to create a magnetic reaction within the part. Discontinuities in structure are flux leakage points and are easily located by use of appropriate instruments or equipment.

MAGNETIC VARIATION. The angular difference between magnetic north and true north. It varies with position on the earth's surface and over long periods (measured in years).

MAGNETIC WIRE. Wire capable of storing information by undergoing changes in magnetization conforming to the applied current representing the desired information.

MAGNETISM. The science treating of the laws and conditions of magnetic force and its effects, or that agency or quality to which magnetic force is due. (See also **magnet**; **electromagnet**.)

MAGNETIZING CURRENT. The component of current drawn by an inductor, magnetic amplifier, transformer, etc., which is required to establish the alternating component of flux.

MAGNETOHYDRODYNAMICS. The science that treats of the dynamics of a fluid which interacts with a magnetic field. It is therefore restricted to those fluids which conduct electricity. This requirement obviously suggests the liquid metals, and explains why early work in the field was done with these

materials. More recently, however, it has become concerned with ionized gases (plasmas) because of their great importance under two very different sets of conditions. The first of these is the extremely tenuous state of matter in space and on celestial bodies whose atmosphere or even surfaces are so rarefied that they become highly ionized incident to received radiation.

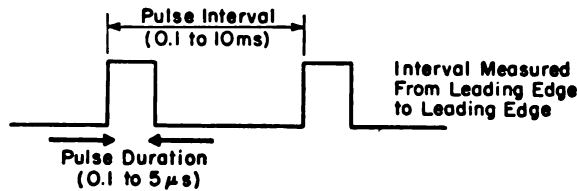
One example of the importance of this phenomenon in astrophysics is the plasma instability occurring in the interplanetary magnetic field. In a treatment of this problem by E. M. Parker, the charged particles of a plasma in a magnetic field tend to move in a manner so as to destroy the isotropy of the pressure tensor. Collisions between particles, on the other hand, tend to restore this isotropy. In the interplanetary gas this competition favors anisotropy as one moves beyond the orbit of the earth. This, in turn, leads to an instability which is enclosing part of the solar system in a shell of irregular magnetic fields. Such a shell had been inferred before, from observations of the slow decay of cosmic-ray activity following solar flares.

The second set of conditions under which the properties of an ionized gas are particularly important is the highly ionized plasmas which are under investigation in the field of thermonuclear energy. Applications of interest in rocketry and astronautics are: (1) thermonuclear reactions, which may furnish power for space ships, magnetic fields providing possible means of "containing" gas plasmas, that is, gases at such high temperatures that they are completely ionized, and therefore responsive to electromagnetic forces. (2) A magnetic type piston used to accelerate ionized particles to the very high exhaust velocities needed for spacecraft traveling at velocities of the order of tens or hundreds of thousands of miles per hour.

MAGNOMETER. An apparatus used for measuring moderate magnetic field intensities, or sometimes the magnetic moments of magnets; frequently both are used, particularly in the determination of the changes from point to point in the earth's magnetic field.

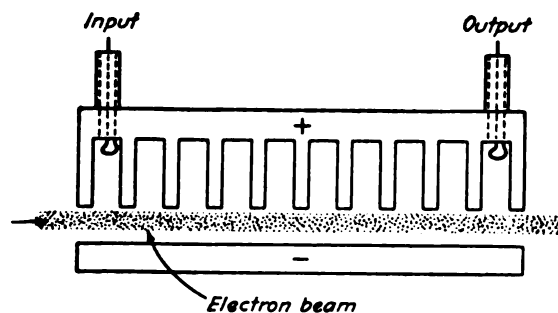
MAGNETOSTRICTION. The term literally implies magnetic contraction, but is generally understood to include a number of closely allied phenomena relating to ferromagnetic substances under magnetic influence.

MAGNETRON. A high-vacuum thermionic tube capable of producing high output power in the microwave region of the frequency spectrum. The tube consists of a heater, cathode, usually a multisegment anode, and an external magnet (electro or permanent) for controlling the unidirectional current flow in the tube which is frequently produced in pulses. (See figure.)



Magnetron pulse relationships.

MAGNETRON AMPLIFIER. A traveling-wave magnetron (see **magnetron, traveling-wave**) used as an amplifier. The basic features of a typical structure are shown in the figure below. It resembles a section of a **vane-type, cavity magnetron** of infinite radius, excited at one end, and coupled to a load at the opposite end. A beam of electrons is projected through the space between the plane electrode and the cavity structure, which is maintained at a positive potential relative to the plane electrode. A magnetic field, normal to the plane of the paper, is adjusted so that the electrons do not strike the anode in the absence of alternating field. If the velocity of the electron beam is equal to, or nearly equal to, the phase velocity with which electromagnetic waves move down the loaded waveguide formed by the cathode and anode, energy is transferred to the electromagnetic



Magnetron amplifier structure. Magnetic field perpendicular to plane of paper. (By permission from "Microwave Theory and Techniques" by Reich et al, Copyright 1953, D. Van Nostrand Co., Inc.)

wave from the source of direct voltage. The electromagnetic wave that moves from the input resonator to the output resonator, therefore, increases in amplitude, and the power output exceeds the power input.

MAGNETRON, PACKAGED. An integral structure comprising a **magnetron**, its magnetic circuit and **output-matching** device.

MAGNETRON STRAPPING. The connecting together of alternate segments of a multiple-cavity resonator in a **magnetron**. This procedure causes only one mode of oscillation to be preferable, and thus increases stability of operation.

MAGNETRON, TRAVELING WAVE. A **magnetron** whose operation depends upon interaction of electrons with a traveling electromagnetic field of constant angular or linear velocity. Most present-day magnetrons such as multicavity and multisegment types belong to this class.

MAGNIFICATION. The ratio of the size of an image formed by an optical system to the size of the object is the most frequent meaning of magnification. However, for a large and distant object, the ratio at the eye of the angle subtended by the image to the angle which would be subtended at the eye by the object itself is also called magnification although it is better stated as **magnifying power**.

MAGNUS FORCE. An aerodynamic force acting on a missile in a direction perpendicular to the XZ-plane. In magnitude the Magnus force is roughly proportional to $\omega \times V$. Where ω is the angular velocity of the missile about a transverse axis, and V is its velocity relative to the surrounding air.

MAIN BANG. Transmitted pulse, within a radar system.

MAIN STAGE. The full-thrust operation of a rocket motor.

MAJOR LOBE. Lobe, major.

MAL. Material allowance list.

MALF-OUT. Malfunction or failure of component.

MAGNITUDE. The order of size of a quantity or entity. For the magnitude of a star, see **star brightness magnitude**.

MALLAUNCHING. Launching in which the constraints imposed on the rocket by the launcher are not removed instantaneously at the moment of launching.

MANEUVER. (1) In space flight, a controlled change of orbit usually by means of thrust force (impulse maneuver), but possibly also by utilizing a perturbation force (perturbation maneuver). (2) In aerodynamic flight, a change in flight path to meet a tactical requirement, usually produced by aerodynamic normal forces.

MANEUVER, CAPTURE. In space flight, change from an open (parabolic or hyperbolic) orbit to a closed (elliptic) orbit near a celestial body.

MANEUVER, CORRECTION. In space flight, a change of orbit for the purpose of obtaining closer agreement with a pre-calculated orbit.

MANEUVER, ESCAPE. In space flight, a change from a closed orbit to an open orbit near a celestial body.

MANEUVER, IMPULSE. Maneuver.

MANEUVER, PERTURBATION. Maneuver.

MANEUVERABILITY. The ability of a missile to alter its flight path to meet tactical requirements; specifically that structural or aerodynamic quality in a missile or aircraft which determines the magnitude and rate at which its attitude and direction of flight can be changed. Commonly expressed in "g's."

MANGANESE. Metallic element. Symbol Mn. Atomic number 25.

MANGANESE DIOXIDE. A chemical compound, having the formula MnO_2 . It is a catalyst for the decomposition of hydrogen peroxide.

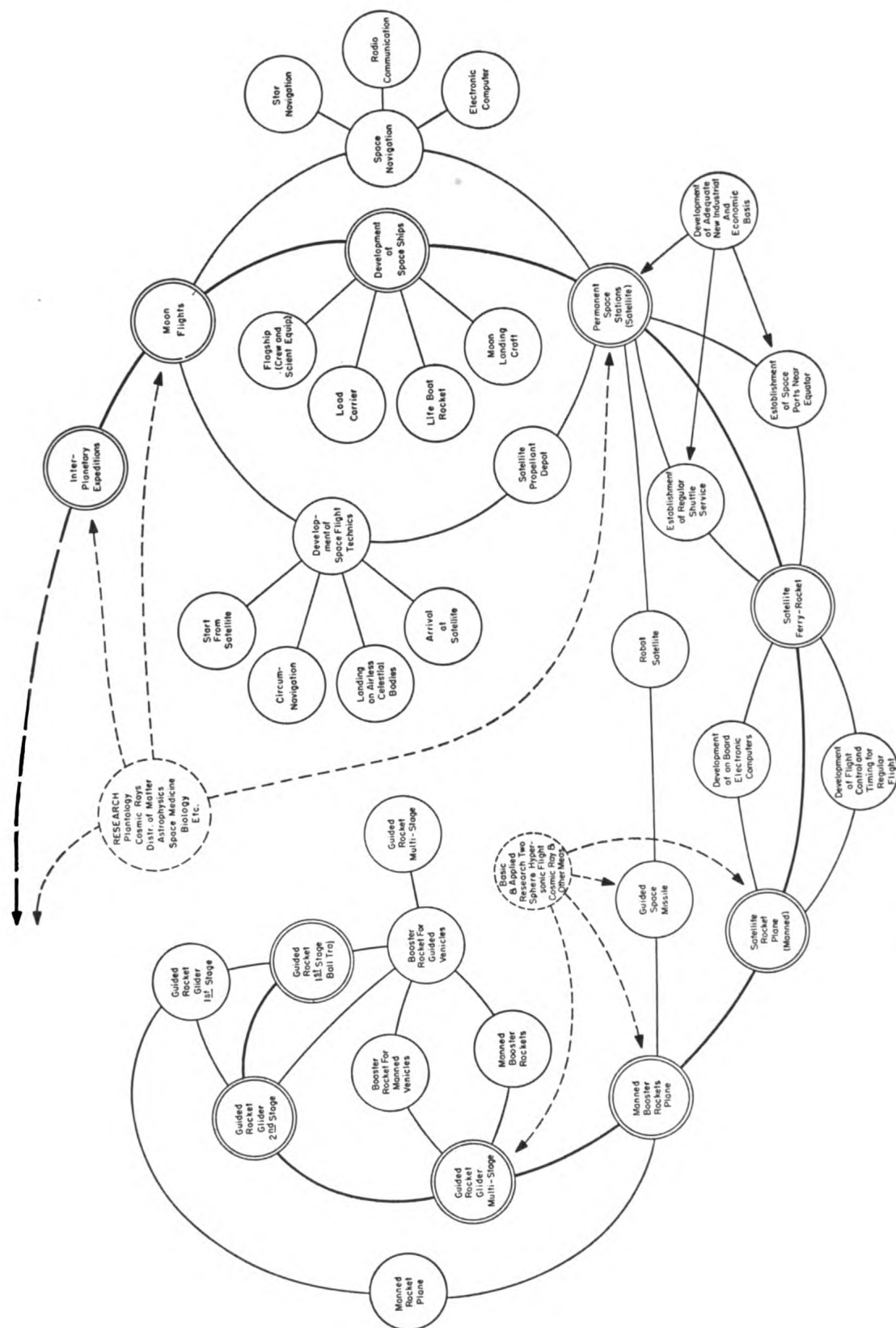
MAN-IN-SPACE. A project sponsored by the National Aeronautical Space Administration having the ultimate objective of placing a man in an orbiting satellite and safely returning him to earth. An Atlas D missile is to be used as booster and a capsule will serve as the inhabited payload. The capsule is teardrop in shape, having the apex forward during launching and the base forward during reentry and

landing. The man lies on his back such that all accelerations are experienced in the reclining position. The capsule is equipped with an escape rocket to pull it clear of a malfunctioning booster, jet reactive controls for attitude stabilization, physiological and environmental instrumentation, air-to-ground communication, a parachute for descent, inflated bags for impact and various aids to recovery from the water. In normal operation the capsule will encircle the earth several times to establish an accurate ephemeris. Descent will then be initiated upon command. In an "abort" operation the escape rocket pulls the capsule to some 2500 feet altitude where the recovery sequence is initiated. A major design precept is the pilot's safety. Accordingly each vital subsystem is capable of both automatic and manual control. Demonstration of high reliability for both the booster and capsule is prerequisite to manned flight. Thus the first man to orbit the earth in space is expected to do so about 1960.

MANIPULATIVE DECEPTION. Deception, manipulative.

MANNED HEMISPHERE. A model of a recoverable reentry satellite recently released by the National Aeronautics and Space Administration. It has controls, instruments and a man in an insulated compartment. The man could turn from his ascent position for support during reentry. Retro-rockets would be used to start reentry. Other equipment consists of fins for roll stabilization, equipment for internal temperature control and oxygen supply, and a parachute for use in the return landing. (See illustration facing Page 507.)

MANNED SPACE FLIGHT. If one accepts the colonization of other celestial bodies and their possible development toward a higher social state as an inevitable consequence of the present growth of space-going vehicles, then space flight by man must be regarded as the principal type of space operation, and even the most sophisticated instrumental space vehicles are but a preparatory step in the evolution of manned space flight. Manned space flight may be divided into two principal regions of operation: inside the solar system (astronautics); beyond the solar system (cosmonautics). Astronautic flights are, therefore, inside the solar system, that is,



Phases of development leading toward interplanetary flight.

interplanetary flight. As shown in the figure on Page 373, astronautics may be divided, for purposes of convenient consideration into four phases: (1) The manned orbital vehicle (satellite rocket plane); (2) the permanent space station (satellite); (3) operations in cislunar and lunar space; (4) interplanetary flight. The first of these, the manned orbital vehicles, capable of operating for a limited time at the outer fringes of our atmosphere, can be the outgrowth of present development work on large guided missiles, research airplanes, and special booster rockets or manned (winged) boosters for multi-stage rocket vehicles. The automatic vehicles are being perfected as long-range guided missiles (intercontinental), and as orbital vehicles (instrumental satellites), comprising various modifications of the instrumental satellite as the forerunner of the automatic (unmanned) earth-to-orbit cargo ship for the establishment and supply of manned satellites.

The manned vehicle leads, via the orbital passenger vehicle (satellite ferry rocket), to the establishment of a permanent, manned satellite.

The third phase is characterized by expansion into cislunar space and is expected to culminate in flights to the moon (satellitory maneuvers and landing operations). This phase comprises a number of activities, such as the establishment of temporary orbits where needed (e.g., satellite propellant depots in orbits of departure), and of additional permanent satellites. Another very important aspect is the development of suitable space ship systems, space flight techniques, and navigational methods. The space ship systems are specialized in regard to their functions, their propulsive systems, and their environmental provisions. This third phase presents so great a variety of technical problems that its solution will have made man truly space-borne so that he is ready to undertake interplanetary operation and move into the fourth phase.

MANOMETER. An instrument for measuring pressure, usually by its action in raising the level of a column of liquid.

MANOMETER, HOT-WIRE. A manometer which measures the pressure of a fluid by the velocity of flow produced through a tube containing a heated wire. The cooling effect

upon the wire is calibrated against the rate of flow, and hence the pressure.

MANOMETER, LIQUID. A manometer in which the pressure to be measured is balanced by the pressure of a column of liquid, often contained in a U-shaped tube.

MAN-YEAR. An effort equal to that of one person for one year. (It is taken as equivalent to 2080 man-hours of paid work. The somewhat lesser number of effective man-hours obtained from one man-year will depend upon local conditions and the type of personnel involved. The normal number of effective man-hours per man-year is approximately 1768.)

MAP. (1) A graphical representation of a portion of the earth's surface to scale, using conventional signs and symbols for topographic and man-made features. (2) A graphical representation of a region of the sky showing the celestial bodies, which is often called an astronomical map or celestial map. The standard military map is the Universal Transverse Mercator (UTM), and the Universal Polar Stereographic (UPS). UTM is used between 80°S and 80°N. The polar regions are shown on the UPS. (See also entries under Cadastral, Contour, Hydrographic, Planimetric, Topographic, Gnomonic, Lambert Conformal Projection, Mercator, Polar Chart, Polyconic, and Transverse Mercator.)

MAP MATCHING. A guidance method in which a terrestrial reference is used. An airborne map obtained from reconnaissance is compared with actual terrain for guidance information.

MARGIN OF SAFETY (MS). As used in missile design, the percentage by which the ultimate strength of a member exceeds the design load. The design load is the applied load, or maximum probable load, multiplied by a specified factor of safety. The use of the terms margin of safety and design load in the above sense is practically restricted to aeronautical engineering.

MARGINAL TESTING. A procedure for system checking which indicates when some portion of the system has deteriorated to the point where there is a high probability of a resultant system failure during the next operating period.

MARKER BEACON. A low-power transmitter placed along established airline routes for guidance purposes.

MARKER FLARE. A pyrotechnic device employed in a missile in flight tests to mark an event of significance, e.g., fuze actuation; the light or smoke emitted is photographically recorded.

MARKER PIP. An identification pulse which is superimposed on some form of cathode-ray tube display to indicate the position of a definite frequency, time or phase.

MARRIAGE. The process of uniting physically the missile stages and all major subsystems.

MARS. (For table of data, see **planet**.) Mars, the "ruddy planet," is the fourth planet in order of distance from the sun. It has been observed from remote antiquity since its ruddy color and relatively rapid motion among the stars make it a very conspicuous object. Within the past 50 years there has been a great deal of speculation relative to the possibility of there being intelligent life on this planet, and, for this reason, there has probably been more printer's ink expended in pseudo-scientific articles about conditions on Mars than on any other astronomical object, with the possible exceptions of the sun and moon.

Since the **orbit** of Mars lies entirely outside the orbit of the earth, the planet can never be seen in the crescent **phase**. However, at quadrature, Mars does present a distinctly gibbous-phase condition as seen with a telescope.

Mars is best observed at opposition, for during this configuration it is on the meridian at midnight. The distance from the earth at an average opposition is about 78,200,000 kilometers (48,600,000 miles), but at a "favorable opposition" (i.e., with the earth at **aphelion** and Mars at **perihelion**) this distance is reduced to 55,700,000 kilometers (34,600,000 miles). These favorable oppositions occur at intervals of from 15 to 17 years.

MARTIAN PROBES. Planetary probes.

MASALCA. A French Navy surface-to-air missile.

MASER. The term has been formed from the phrase "microwave amplification by stim-

ulated emission of radiation." It refers to devices made with gases or solids in which atoms or molecules can be raised to a high energy level at which they are unstable. A signal will cause them to radiate excess energy at a specific wavelength. Energy emitted greatly exceeds incoming signal. Gaseous masses produce uniform and precise oscillations. Consider a stream of particles in equilibrium for a given energy transition, that is, some are emitting radiation at the frequency of the transition and others are absorbing it. In the maser such a stream of particles is passed through a focuser in which an electric field disperses the low-energy particles and concentrates the high-energy ones. The latter are then passed into a cavity resonator, which has been adjusted in size to resonate at precisely the frequency of the radiative transition of the particles. This reinforces the radiation emitted by the particles, and sets up a strong oscillation, so that the apparatus can be used for various control purposes. The first of these was the atomic clock of C. H. Townes, J. P. Gordon and H. J. Zeiger of Columbia University, who coined the word "maser." They used as their working substance ammonia molecules in an excited state. Since the maser has produced the narrowest frequency range ever obtained, and the most stable, its use for controlling a **clock** is obvious.

However, the maser may be used in other ways. If the supply of particles to the cavity resonator is kept below that needed to maintain oscillations, it can be used as an amplifier (for microwave signals of the corresponding frequency).

MASKING. The condition where a part of the missile structure blocks a portion of the warhead emission, fuze sensing area, or electromagnetic radiation area.

MASS. (1) The physical measure of the principal inertial property of a body, i.e., its resistance to change of motion. At speeds small compared with the speed of light, the mass of a body is independent of its speed. Under these circumstances, the masses m_1 and m_2 of two bodies may be compared by allowing the two bodies to interact. Then

$$m_1/m_2 = |a_2|/|a_1|,$$

where $|a_1|$ and $|a_2|$ are the magnitudes of the respective accelerations of the two bodies as

a result of the interaction. This permits the measurement of the mass of any particle with respect to a standard particle (for example, the standard kilogram). At higher speeds, the mass of a body depends on its speed relative to the observer according to the relation:

$$m = m_0 / \sqrt{1 - v^2/c^2}$$

where m_0 is the mass of the body as found by an observer at rest with respect to the body, v is the speed of the body relative to the observer who finds its mass to be m , and c is the speed of light in empty space.

As a consequence of the Newton law of universal gravitation or of the Einstein demonstration of the equivalence of inertial and gravitational masses, equal masses at the same location in a gravitational field have equal weights. Because of this, masses may be compared with a platform balance or a spring balance.

(2) Mass in a mechanical oscillatory system is that coefficient which, when multiplied by 2π times the frequency, gives the positive imaginary part of the **mechanical rectilinear impedance**. The unit is the gram.

MASS ACCELERATOR. Light gas gun.

MASS DENSITY. The density of a substance expressed in mass units rather than weight units. That is, slugs per cubic foot rather than pounds per cubic foot. Slugs per cubic foot are equivalent to $\text{lb-sec}^2/\text{ft}^4$. Its symbol is Greek letter rho (ρ). (See **units and dimensions**.)

MASS FLOW. The rate of flow of a substance. The term is often used in jet propulsion to denote the mass of propellant material per unit time emerging as exhaust gases from a rocket motor. It is designated as \dot{m} , ("M-dot"), and is also called the "mass rate of flow." It is expressed mathematically as:

$$\dot{m} = \frac{dM}{dt} = \rho A v$$

where \dot{m} is the mass flow, M is the total mass of propellant, t is the time, ρ is the density of the material, A is the cross-sectional area of the duct, and v is the velocity of flow. The mass flow rate is one of the factors determining the **thrust**, since according to Newton's Second Law, the force equals the mass multiplied by the acceleration. The theoretical

thrust of a rocket motor is equal to the mass of matter ejected multiplied by the acceleration given to it during the process.

MASS NUMBER. The whole number nearest in value to the atomic mass when that quantity is expressed in atomic mass units. In light of present-day theory, the mass number represents the total number of nucleons in the nucleus, and is therefore equal to the sum of the **atomic number** and the **neutron number**. The mass number is commonly written as a superscript after or before the symbol of the atom, such as O^{16} or a^{40}K .

MASS RATIO. The ratio of the take-off weight of a rocket (M_0) to its burn-out weight (M_1). (Burn-out weight is the rocket empty of fuel but including payload weight.) Mass ratio is expressed as:

$$\text{M.R.} = \frac{M_0}{M_1}$$

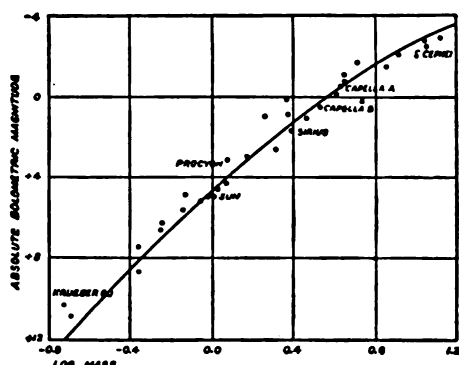
where $M_0 = M_R + M_F + M_P$ and $M_1 = M_R + M_P$, where M_R is the mass of the rocket, M_F is the mass of the fuel, M_P is the mass of the payload.

If $M_0/M_1 = 2.72$, a single stage rocket would attain a velocity equal to its own exhaust velocity. A still greater mass ratio of 6 or 7 to 1 would be required to enable it to leave the earth's atmosphere; while a mass ratio of the order of 100 to 1 would be necessary for it to leave the earth's gravitational field, that is, to attain **escape velocity**. These values assume the use of conventional fuels. Their relatively great magnitude is due to the fact that the velocity obtained by a rocket is roughly proportionate to the logarithm of the mass ratio, that is, $v = c \ln R$, where v is the final velocity, c is the exhaust velocity, and R is the mass ratio. It should be noted that these statements do not apply to multistage vehicles.

In some usages the mass ratio is defined as the reciprocal of the value given above, that is, as the ratio of the burn-out weight to the take-off weight.

MASS-LUMINOSITY RELATION. From purely theoretical reasoning, based upon the hypothesis that the material of which a star is constructed follows the gas laws, Eddington was able to show that there should be a relationship between the mass and the total radiation from a star. The details of the theory

are far too complex to be included here, but it should be emphasized that the conclusions are based upon purely theoretical reasoning and not upon a statistical study of previously determined masses and **absolute magnitudes**. The results obtained from the theory are graphically represented by the curve shown in the accompanying figure. The curve was



Mass-luminosity curve. (From a diagram by Ed-
dington.)

calculated from pure theory and the plotted points represent stars with observationally determined masses and luminosities. The agreement between theory and observation is remarkably close for **giant and dwarf stars** of all **spectral classes**. The only class of stars for which the theory completely fails to agree with observational results is the abnormal group known as the **white dwarfs**.

MASTER EQUIPMENT ALLOWANCE LIST (MEAL). A publication that prescribes allowances of organizational equipment to be authorized to Technical Operation units through the medium of the unit mission equipment column of the Unit Authorization List.

MASTER OPERATIONAL CONTROLLER (MOC). The central control and monitoring point for all **launch** station activities necessary for preflight checkout, countdown sequencing, firing, and post-firing deactivation.

MASTER STATION. In a hyperbolic navigation system, that station in a given pair of transmitting stations that controls the transmissions of the other station in the pair (the slave station) and maintains the time relationship between the pulses of the two stations.

MATADOR. A U.S. Air Force tactical surface-to-surface aerodynamic missile. It was developed by the G. L. Martin Company, and was first U.S.A.F. "nuclear" guided missile sent into operations service (March, 1954). Its first flight was on January 20, 1949 at Holloman Air Force Base, New Mexico. It has a swept wing mounted high in the middle of the fuselage with negative dihedral. Range is several hundred miles. Guidance is by means of ground guidance stations using a form of radio command. The Matador was first identified as the B-61. This was changed in 1955 to TM-61. The TM-61 passed through several versions, TM-61A, and 61C. Later versions were generally of greater speed and range. Thus, the TM-61C has a speed of 650 m.p.h., a length of 39 ft. 8 in., a span of 28 ft. 8 in., and a guidance system improved over earlier types. It is powered by an Allison J-33-37 turbojet, and is ground-launched from a rocket booster from a roadside launcher. It can be controlled electronically in flight. It is a predecessor of the **Mace**. (See **missile guided**.) (See also illustration facing Page 251.)

MATCHED TERMINATION DEVICE. A matched transmission line or waveguide that has no reflected wave at any transverse section. (See **matching impedance**.) It effects the complete transmission of energy received.

MATCHING IMPEDANCE. The technique of minimizing the **standing-wave ratio** when two devices having unlike **impedances** are coupled. This process, at the same time, maximizes power flow between the two devices, assuming one to be a source and the other a sink.

MATERIAL FACTOR. A **factor of safety** included because of uncertainty of material strength.

MATERIAL—GUARANTEED MINIMUMS. Physical properties of materials which are expected by the producer to be minimum and therefore are guaranteed. Tensile ultimate and yield are usually the only guaranteed values—all others being on a derived basis.

MATERIAL—90% PROBABILITY VALUES. Physical properties of materials which are expected to be obtained or exceeded by 90% of the material delivered by the producer.

These are statistical values based on facts for tensile ultimate and yield; other properties are derived.

MATERIALS SYMBOLS. In standard engineering drawings, there are conventional patterns to denote common materials. In the "simplified" drafting technique being used by many manufacturing concerns today, these time-consuming designations are replaced by verbal notations on the drawings.

MATRIX. 1. A mold, e.g., in the graphic arts industries, a shell for casting type. 2. In color photography, printing film for the transfer of an image to another support. Dyed relief films or differentially hardened films are generally called matrices when used in an **im-bibition** process. 3. In mathematics, the term matrix is used in the following way. Consider a set of elements, finite in number, which may be arranged in rows and columns. If A_{ij} , B_{ij} are the elements in i th row and j th column of two such arrays and if these arrays combine to form a product with elements $C_{ij} = \sum A_{ik}B_{kj}$, then they are called matrices. A convenient symbolism is A , B , $C = AB$.

MAULER. A U.S. Army surface-to-air missile intended for low altitude air defense, announced in 1958 as a replacement for light antiaircraft artillery.

MAXIMUM ORDINATE. The distance from the center of the earth to the apogee of a missile trajectory or, alternatively, this distance minus the radius of the earth.

MAXIMUM SOUND PRESSURE. Sound (acoustomotive) pressure.

MAXWELL EQUATIONS. A set of four classic formulae of the **electromagnetic theory**. They deal with certain vector quantities pertaining to any point of a region under varying electric and magnetic influence. If the point is in empty space, the equations are somewhat simplified; in general, provision must be made for the presence of dielectrics, conductors, or magnetizable bodies. In these equations, H is magnetizing force, B is magnetic induction, E is electric intensity, D is electric induction, ρ is electric charge density, J is conduction current density, t is time. The "curl" and the "divergence" of a function are well-known operators of vector analy-

sis. The equations, in rationalized mks units, are

$$\text{Curl } H = \frac{\partial D}{\partial t} + J$$

$$\text{Curl } E = -\frac{\partial B}{\partial t}$$

The additional relations

$$\text{Div } B = 0$$

$$\text{Div } D = \rho$$

are frequently included as part of Maxwell's system, although they are not independent relations if one assumes the conservation of charge. The last two are also known as the **Gauss law**. For linear homogeneous isotropic media, $B = \mu H$; $D = \epsilon E$. The values of μ and ϵ for a vacuum satisfy

$$\mu_0 \epsilon_0 = 1/c^2$$

where c is the speed of light.

MAYDAY. The radio-telephone international distress call.

MB. Munitions Board.

MB-1. Genie.

MC. Megacycles.

MCW. (An abbreviation for "modulated continuous wave.") A form of emission in which the **carrier** is modulated by a constant audio-frequency tone. In telegraphic service, it is understood that the carrier is keyed.

Md. Mendelevium.

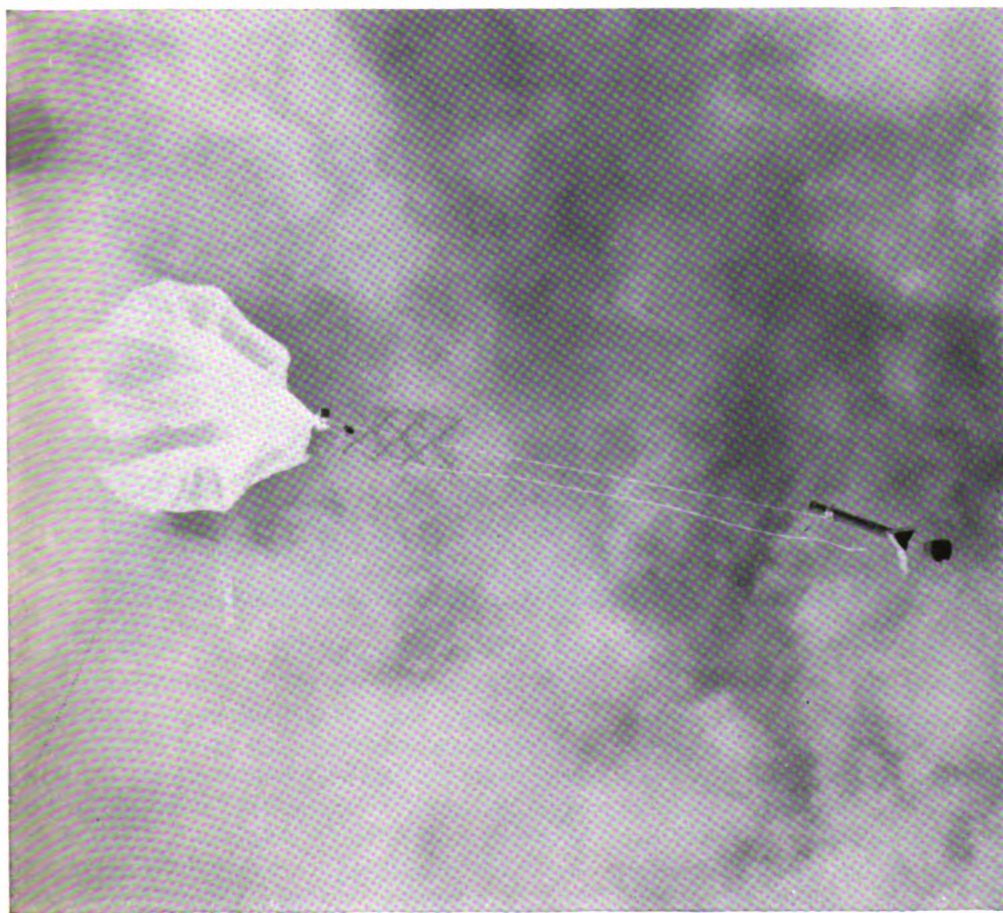
MEACONING. A system for receiving electromagnetic signals and rebroadcasting them with the same frequency so as, for instance, to confuse navigation. A confusion reflector, such as **chaff**, is an example. (See **jamming**; **countermeasures**.)

MEAL. Master equipment allowance list.

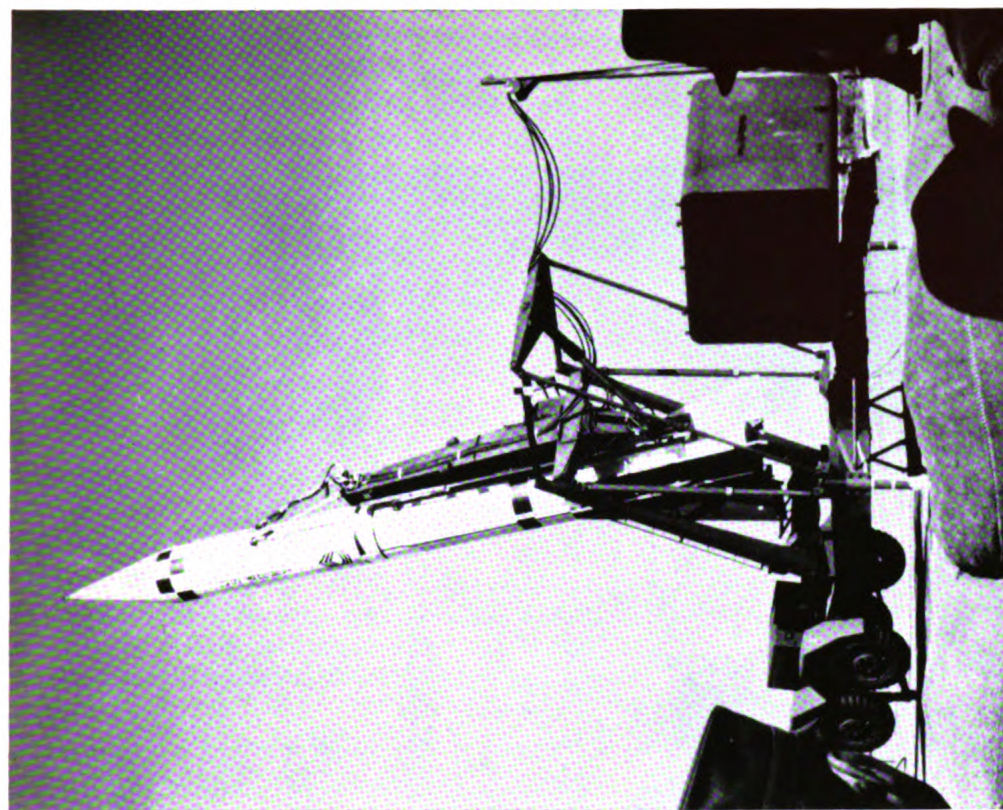
MEAN ABSOLUTE ERROR (MAE). In measurement theory, the arithmetic mean of all errors without regard to sign. Also termed the average error.

$$\text{M.A.E.} = \frac{\sum |X_i - \bar{X}|}{n}$$

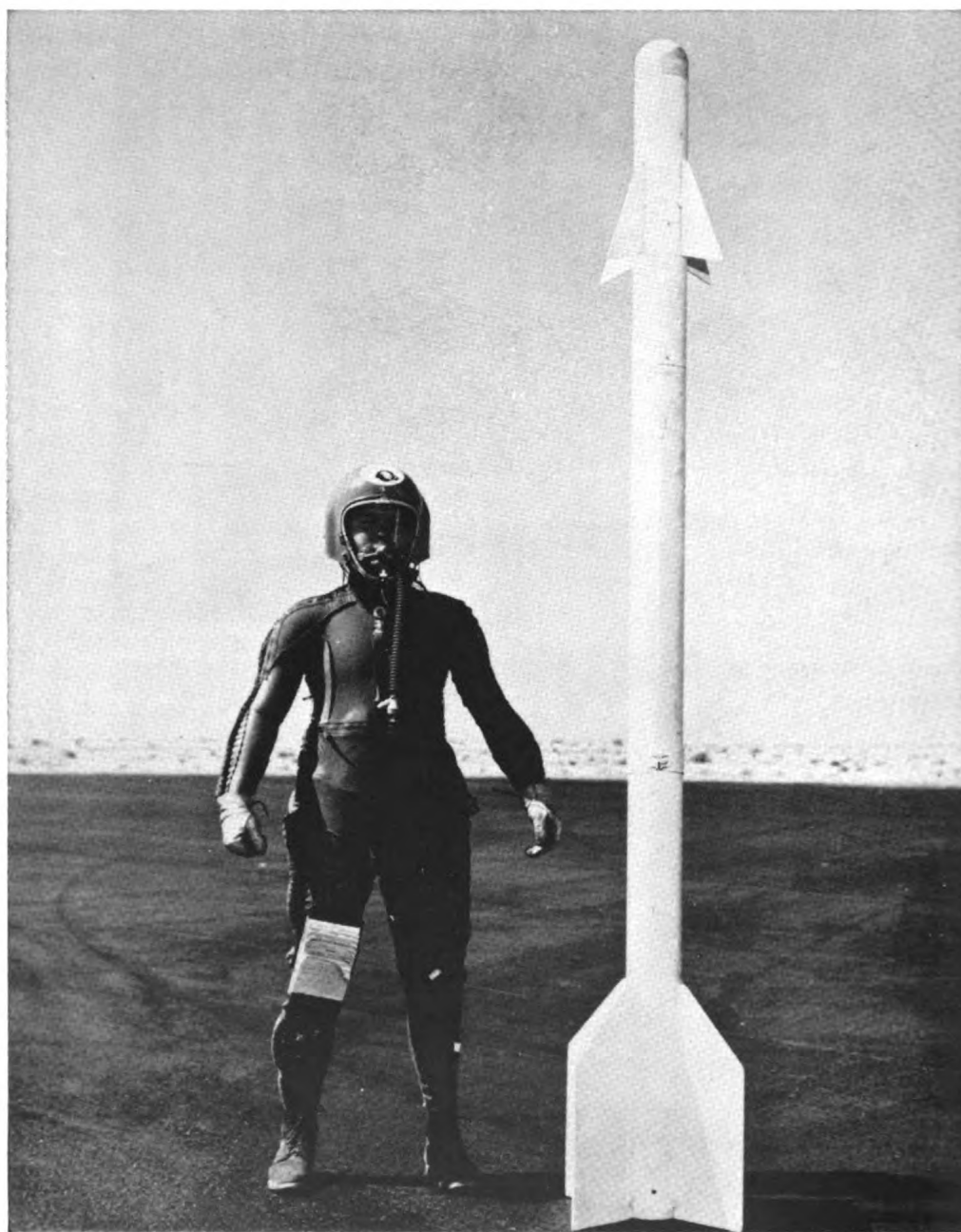
(See illustration in article on **normal distribution**.)



Balloon-supported ROCKOON ascending after being launched by radio signal from shipboard. The ROCKOON floats above the ocean until a solar flare is observed. At this time, a radio signal from the transmitter aboard the ship fires the rocket. The rocket is designed to reach an altitude of 60-70 miles above the earth and to radio back to the observing station aboard the ship data on the radiations from the solar flare. (*U.S. Navy Photograph*)



A U.S. Army SERGEANT surface-to-surface guided ballistic missile readied for launching at the White Sands Proving Ground. The SERGEANT missile is under development by the Jet Propulsion Laboratory, California Institute of Technology in cooperation with the Sperry Gyroscope Company, which is the contractor for production. (*U.S. Army Photograph*)



Pilot in high-altitude flight suit stands beside the SIDEWINDER missile. (*U.S. Navy Photograph*)

MEAN AERODYNAMIC CHORD. The chord of an assumed rectangular airfoil, representing the **mean chord** of an actual airfoil.

MEAN ANOMALY AT EPOCH. Satellite elements.

MEAN CHORD. That chord of an airfoil that is equal to the sum of all the airfoil's chord lengths divided by the number of chord lengths added.

MEAN ERROR. In measurement theory, the mean value of an error as contrasted to the spread of errors about that mean value. Also termed arithmetic mean, algebraic average, and bias.

MEAN FREE PATH. (1) The distance the average molecule in a gas travels before striking another molecule. Mean free path is related to the kinematic viscosity of a gas as follows:

$$\nu = 0.499 \bar{v} l$$

where ν is the kinematic viscosity, l is the mean free path, and \bar{v} is the mean free velocity. The mean free path of the molecules of a gas is given by:

$$l = \frac{1}{5.66 r^2 \pi N} \text{ centimeters}$$

where r is the average radius of the gas molecules (1.87×10^{-8} centimeters for air), and N is the number of molecules per cubic centimeter (for air, $2.08 \times 10^{22} \rho$), where ρ is the density.

At sea level conditions the mean free path of a molecule is a very small fraction of an inch. As altitude increases, the atmospheric density drops because there are less molecules in a given volume of air and the mean free path increases manyfold.

The value of the mean free path is related to the frictional heating effect of air during the passage of high Mach number flying objects. One of the latest theories of frictional heating predicts that temperatures actually increase with mean free path after a certain point, because the air molecules are so highly dissociated that their individual impacts on a supersonic body cause greater heating than at lower levels where the continuity of the medium permits conduction of thermal energy between the molecules. The mean free path of air molecules in the atmosphere increases with altitude approximately as follows:

ALTITUDE	MEAN FREE PATH
Sea level	7.4×10^{-7} foot
40 miles	1 inch
75 miles	1 foot
150 miles	300 feet
400 miles	40 miles

(2) In acoustics, mean free path is the average distance sound travels between successive reflections in an enclosure.

MEAN LIFE. Life, mean.

MEAN MIXTURE RATIO. The mean mixture ratio is equal to the average oxidizer flow rate, divided by the average fuel flow rate, within the 90 percent-of-rated thrust ordinates of a curve made of a complete firing on a rocket engine or gas generator.

MEAN MOTION. Satellite elements.

MEAN SUN. The mean, or average, sun is a purely fictitious object used as a reference point for measuring mean or civil time by the rotation of the earth. The term mean sun comes from the fact that the day as determined by use of it, i.e., the mean solar day, is very nearly equivalent in length to the average of the lengths of the different apparent solar days throughout the year.

The apparent motion of the true sun through the stars is produced by the actual motion of the earth in an elliptical orbit about the sun, the plane of which is inclined to the plane of the equator. To remove the irregularity in the apparent motion of the sun due to the elliptical motion of the earth, a fictitious object is assumed to move in the plane of the ecliptic with constant angular velocity which passes through perihelion coincident with the true sun. The mean sun is a fictitious object assumed to be moving in the plane of the equator with constant angular velocity passing through the vernal equinox coincident with the fictitious object just defined.

MEAN SOLAR DAY. A day which is the average, in length, of all apparent solar days in a given year. A purely fictitious object, known as the mean sun, was defined and a mean solar day is the interval between successive passages of this fictitious object across any local meridian. The mean solar day begins at lower culmination of the mean sun and local mean time is the hour angle of the mean sun plus 12 hours. The difference be-

tween local apparent time and local mean time, taken in the algebraic sense of apparent minus mean, is known as the **equation of time**.

MEAN SOLAR TIME. Civil time.

MEAN TIME. Time reckoned by reference to the **mean sun**.

MEAN-TIME BETWEEN FAILURES (MTBF OR M). Of a complex system (in which failed parts are replaced with new parts of equal failure rate), essentially the average time between outages caused by catastrophic failures. It can be determined by dividing the product of the number of equipments tested (N) and the test time (t) by the number of failures (f) which occur during that time, i.e., mtbf or often just $m = \frac{Nt}{f}$.

" m " is the reciprocal of λ i.e., $m = \frac{1}{\lambda}$ and is related to the probability of survival by the exponential failure law $P_f = e^{-\lambda/m}$. The figure of merit " m " is convenient for use in determining if the reliability of an equipment

lowing mechanical rectilinear elements: mechanical rectilinear resistance, **mass** and **compliance**.

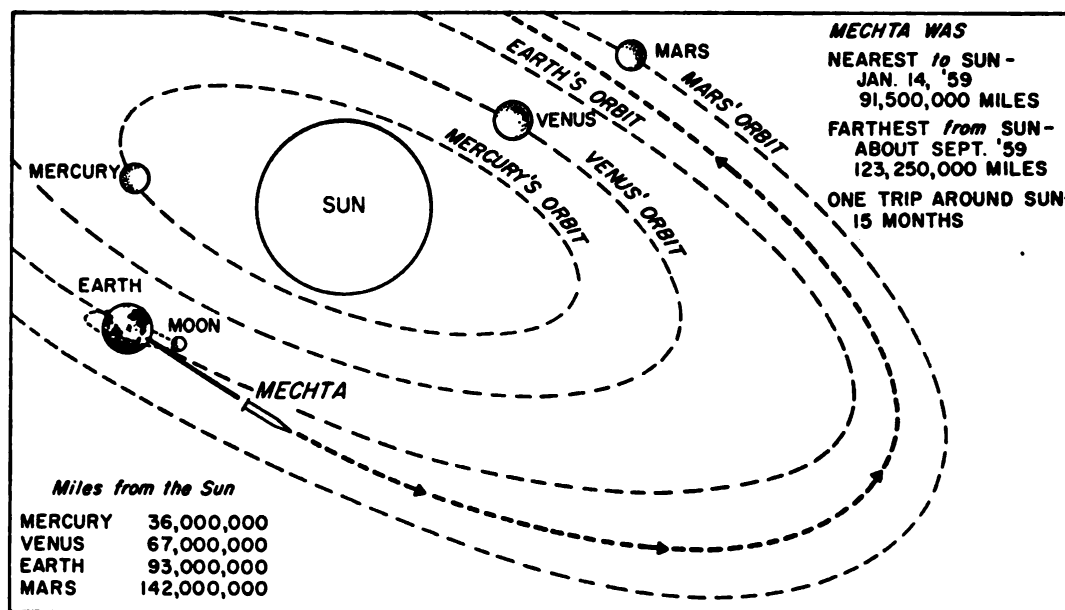
MECHANICAL ROTATIONAL SYSTEM.

A system adapted for the transmission of rotational vibrations consisting of one or all of the following mechanical rotational elements: mechanical rotational resistance, **moment of inertia** and rotational **compliance**.

MECHANICAL SYSTEM. An aggregate of matter which possesses mass and whose parts are capable of relative motion.

MECHTA (LUNIK). An historic rocket launched by the Soviet Union on January 2, 1959 which became man's first artificial asteroid.

Mechta's final stage weighed 3200 pounds, of which 797 pounds comprised an instrumentation package. It achieved escape velocity, passed about 4500 miles from the Moon some 34 hours later and entered orbit on January 7, 1959. Its orbit, as compared to Earth's and other planets', is illustrated below.



is likely to be adequate for missions of specific lengths.

MECHANICAL BORDER. The level in the atmosphere (at about 120-140 miles altitude) where air resistance and friction become negligible.

MECHANICAL PILOT. Automatic pilot.

MECHANICAL RECTILINEAL SYSTEM. A system adapted for the transmission of linear vibrations consisting of one or all of the fol-

Since transmission from telemetrical transmitters ceased shortly after passage near the moon and since future passages near the earth are not predicted it is likely that Mechta will never again be observed. It is hoped that valuable information will be gained from attempted measurements of the Moon's magnetic and radiation fields (if any).

MEDIUM FREQUENCY. A frequency of 300-3000 kc/s as used in electromagnetics. It is abbreviated MF.

MEISSNER OSCILLATOR. An oscillator in which the grid and plate circuits are inductively coupled through an independent tank circuit which determines the frequency.

MEMORY. Any device into which information can be introduced and then extracted at a later time. The mechanism or medium in which the information is retained commonly forms an integral part of a computer.

MEMORY UNIT. In computer usage, a memory device in which data required for computation are stored until needed.

MERCATOR PROJECTION. A means for portraying the earth's surface. To obtain the proper proportion, the meridians are expanded in the same ratio as the parallels. As the latitude increases, the parallels expand on an increasing scale, and accordingly the meridians expand in proportion. To compensate for this error, different scales must be used on Mercator charts for measuring distances in different latitudes. The expansion of the latitude and longitude scales approximates, for short distances, the secant of the latitude.

MERCURY. (1) Metallic element. Symbol Hg. Atomic number 80. (2) The planet Mercury (for table of data, see **planet**) is the closest planet to the sun of those thus far discovered. It has been known from remote antiquity and there are recorded observations of it as far back as the 3rd century B.C. Mercury is so close to the sun that at its maximum elongation it is less than 30° away, as seen from the earth, with the result that it will never rise more than two hours before the sun, nor be above the horizon in the evening more than two hours after sunset in the latitudes of the United States. The early astronomers failed to recognize the planet as the same object when seen east and west of the sun; it being known as Apollo when seen west of the sun in the early morning, and as Mercury when seen east of the sun in the evening.

As well as being the closest planet to the sun the orbit of Mercury is the most eccentric of all planetary orbits. This high eccentricity, coupled with the proximity of the sun, give to the planet a velocity of more than 36 miles per sec. when at perihelion, a value more than twice as great as that for the earth. After orbits had been computed on the basis of the Newtonian and Keplerian laws and all perturbations applied for the gravitational ef-

fects of all known planets, there still remained a progressive motion of the longitude of **perihelion**. For many years this unexplained perturbation was attributed to the attractions of an unknown planet between Mercury and the sun. The search for this intra-mercurial planet, provisionally called Vulcan, formed a part of many **eclipse** programs during the past century. The application of the theory of relativity to the orbit calculations for Mercury removed this hitherto unexplained perturbation and was one of the early triumphs of the theory.

MERCURY ARC. The electric discharge through mercury vapor, between electrodes either of mercury or of some solid metal, is among the richest sources of **ultraviolet** radiation and has long been used as such. In the more common forms now in use at least one electrode is of mercury, deposited in a suitable reservoir at the end of a quartz tube. As these tubes are operated on moderate voltage, it is necessary to start or "strike" the arc by temporarily running a small stream of mercury through the tube from one electrode to the other. This makes a mercury conductor which quickly grows hot and fills the tube with mercury vapor, after which the mercury stream is broken and the arc is self-sustaining. The temperature is not nearly so high as in solid-electrode arcs, and these lamps are quite efficient.

MERCURY FULMINATE. An extremely sensitive high explosive of formula, $\text{Hg}(\text{ONC})_2 \cdot \frac{1}{2} \text{H}_2\text{O}$.

MERIDIAN. (1) A great circle of the earth which passes through its poles. The **prime meridian** is the meridian used as the origin of measurement of longitude. The meridian of the original site of the Royal Observatory at Greenwich, England is used by nearly all of the countries in the world as the prime meridian. (2) A great circle on the **celestial sphere** passing through the poles of rotation. Such circles are perpendicular to the **celestial equator**. (3) A line representing such a circle or half circle, as on a globe or as projected on a flat surface.

MERIDIAN CIRCLE. A meridian circle is a telescope adjusted so that the **collimation plane** of the instrument is in the plane of the local meridian, and the telescope may be rotated about a horizontal axis. The instru-

ment is usually fitted with a circle, accurately graduated in degrees, minutes, and seconds, which is perpendicular to the axis of rotation and hence is in the plane of the meridian. In case the instrument does not carry the circle in the meridian, the instrument is known as a transit circle.

At the principal focus of the telescope is placed a reticle with an odd number of vertical wires, the middle one of which is in the collimation plane. One horizontal wire through the optic axis of the telescope is usually present.

The instrument is used to determine the **equatorial coordinates** of the stars, when the local sidereal time and terrestrial **latitude** are known; or, conversely, to determine accurate local sidereal time by observation of stars of known right ascension. The local sidereal time of the instant of passage of a star across the middle wire of the reticle must be the **right ascension** of the star. The declination is obtained from the readings of the graduated circles when the star passes through the field of view along the horizontal wire. The instrument is also used for the accurate determination of terrestrial **longitude** by determining the local sidereal time and knowing the corresponding Greenwich time.

MERIT, SIGNAL-TO-NOISE. Signal-to-noise ratio.

MERU. Milli-earth rate unit, 0.001 part of the daily revolution of the earth.

MESON. Any elementary particle having a rest mass intermediate between the mass of the electron and the mass of the proton. Many types of mesons are produced by cosmic rays. Some are positively-charged, some negatively charged, and some neutral. They differ widely in mass, half-life and other properties.

MESOPAUSE. That altitude (about 50 miles) at which the temperature profile changes. It separates the mesosphere and the thermosphere in the Chapman **atmosphere**.

MESOSPHERE. (1) A sphere or layer of the **atmosphere** between the **ionosphere** and the **exosphere** (about 250 to 650 miles). (2) A sphere or layer of the atmosphere between the top of the **stratosphere** and an unnamed

layer where the minimum of temperature occurs (about 20 to 50 miles). In this sense the mesosphere is coextensive with the chemosphere.

For some purposes the mesosphere is considered to consist of two portions: the meso-incline in which the temperature increases (from about 30 kilometers to 58 kilometers altitude), and the mesodecline in which the temperature decreases again.

MESSIER. Charles Messier (1730-1817), was a French astronomer who cataloged a large number of nebulae and extra-galactic objects. The name Messier alone generally refers to his catalog.

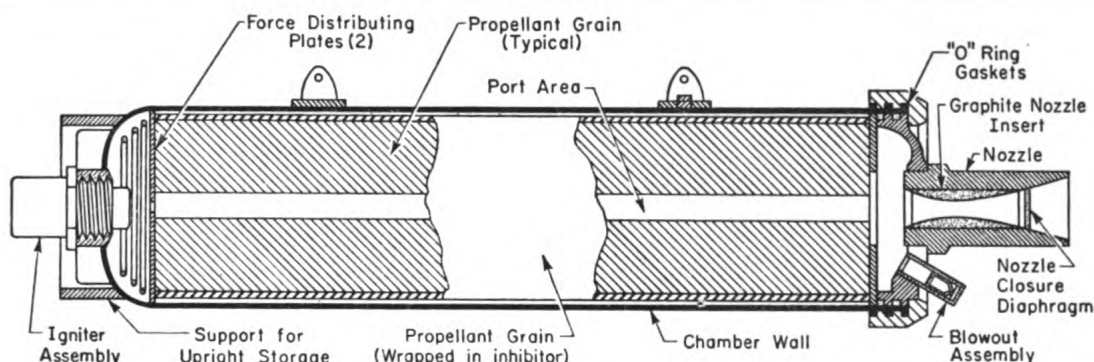
METACENTER. A floating body is in equilibrium if the center of gravity and the center of buoyancy lie on a vertical line. If the body is displaced by a small angle from this position, the center of buoyancy will move, and the intersection of the vertical through the new center of buoyancy and the line joining the center of gravity and the equilibrium center of buoyancy is known as the metacenter. The equilibrium is stable or unstable as the metacenter lies above or below the center of gravity.

METAL PARTS. A generic term inclusively describing the parts of a solid propellant rocket excepting the **propellant charge**, the **inhibitor** (inert liner) and the **igniter**. (Metal parts may comprise between 9 and 40% of the gross weight of a rocket.) (See Figure, Page 383.)

METAL PARTS/WEIGHT RATIO. A term used in solid-propellant rocket design to denote the ratio of the weight of the metal parts to the total weight of the loaded rocket, excluding special fittings and attachments. It equals unity *minus* the propellant/weight ratio.

METASCOPE. A device for transforming invisible infrared rays into visible signals.

METEOR. (1) In astronomy, an aster or particle of material from outer space that enters the earth's atmosphere at a high speed and ignites into a visibly glowing mass as a result of air friction. Estimates set the annual fall of meteors over the entire earth on the order of a thousand tons. Most of these are micrometeorites less than 100 microns in diameter. "Large" meteors are sometimes



Metal parts of solid propellant rocket.

considered to be particles greater than 1 microgram. (2) A U.S. Navy air-to-air missile weighing about 500 pounds, with a maximum speed of 3,300 feet per second with a 25 pound payload. It used a liquid-propellant engine developed by the Bell Aircraft Corporation and the Massachusetts Institute of Technology. The program was cancelled in 1954. (3) A proposal by Darrell Romick, Richard Knight and Samuel Black of Good-year Aircraft for a large-size space station satellite. The name is derived from: *manned earth satellite terminal evolving from earth to orbit ferrry rockets!*

METEOR SHOWERS. Whenever the earth encounters a swarm of meteors revolving together around the sun, a meteor shower ensues. Since the meteors in the swarm are all moving in parallel paths, their luminous trails through the air are parallel, or nearly so. Just as the rails of a track seem to diverge from a point in the distance, so the parallel trails appear to spread from a point or small area in the sky. The radiant of a meteor shower is the vanishing point in the perspective of the parallel trails. It is located by extending the trails backward.

The Perseids furnish the most conspicuous and dependable of the annual showers. They are visible through 2 or 3 weeks, with the greatest display about August 11. Their orbit is nearly perpendicular to the ecliptic plane and passes near the orbit of no other planet. Next in order of numbers and reliability are the Orionids (October 21) and the Geminids (December 10). Among the less frequent showers the Leonids, revolving around the sun in a period of 33 years, produced in 1833 and 1866 the most spectacular showers of modern times. At later returns,

however, they appeared only in sprinkles.

The Draconids have given the most remarkable showers of the present century. They are also known as Giacobinids, because they revolve in the orbit of the Giacobini-Zinner comet, a member of Jupiter's family first noticed in 1900. The comet revolves around the sun in a period of $6\frac{1}{2}$ years. The main body of the swarm, and the earth arrive together at the intersection of their paths in October at intervals of 13 years.

A meteor shower can occur only where the orbit of the swarm crosses the earth's orbit, and when the swarm and earth arrive together at the crossing point. The place of this point on the earth's orbit, of course, determines the date of the shower. If the swarm is condensed, the interval between showers depends on the period of revolution of the swarm around the sun. Swarms extended in streams may spend more than a year in crossing the earth's orbit, or may be so scattered around their orbits that we encounter some of their members every year.

Disturbing effects of the planets frequently alter the meteoric orbits. Some swarms which formerly produced remarkable showers no longer do so. Other swarms now unknown to us may some day be brought to collision with the earth. A conspicuous meteor shower, like a bright comet, may come unheralded at any time.

METEOR, ARTIFICIAL. In October, 1957, the U.S. Air Force conducted a significant and highly interesting astronautic experiment. Several small aluminum pellets were blasted into interplanetary space from an altitude of about 47 nautical miles (about 285,000 feet) by means of **shaped-charges**, carried to altitude and directed properly by an **Aerobee**

high altitude sounding rocket, which experienced engine cut-off at about 190,000 feet and coasted to the altitude where the charge was fired. In a shaped-charge the blast does not expand in all directions, but is oriented in one particular direction, thereby augmenting the momentum of the particles blasted away. The purpose of this test, which occurred over the White Sands desert in New Mexico, was to reverse a meteor entry into the atmosphere from space. The altitude was chosen as being representative for the region in which meteors glow and become visible. Their entry velocity from interplanetary space lies between 35,000 and some 100,000 feet per second. The shaped-charge produced particle-velocities in the neighborhood of 60,000 feet per second. The blast was brightly visible. Subsequently photographs were taken of escaping meteors with the Baker Super-Schmidt camera. Some were as bright as the planet Venus, which is at times the brightest stellar object in our sky, that is about -4th magnitude. By analyzing these trails, made by particles of known size and composition at known altitude and with approximately known speed, it becomes possible, for the first time, to establish an objective calibration scale for computing the size, speed and possible composition of natural meteors entering the atmosphere. Furthermore, by spectroscopic analysis of such trails it is possible to determine the air composition up to altitudes where the density is too low to produce a sufficiently bright trail, even at these velocities. By firing such meteors at different times of the year from such marginal altitudes, differences in trail brightness, if any, would give us an indication of the seasonal variations in the upper atmosphere. Finally, we could by proper analysis of the trails, learn more about the behavior of our upper atmosphere when a fast moving body of known size and speed passes through it (ionization and dissociation). This would be of great interest in the design of hypersonic vehicles and re-entry vehicles. All these tests are relatively inexpensive and their scientific potential is high. But beyond this, they represent an interesting technique of firing small particles at the Moon. It is doubtful, in view of the limited accuracy with which the discharge direction can be controlled, whether very much material would reach the Moon. The impact may not be observable from a surface observatory, but

might be from a satellite with optical equipment. One could also equip optical **hyperbolic probes** (which have to have some form of attitude control) with shaped-charges and fire pellets into the lunar ground at meteor speed with the satellite camera observing the effect. Very much can be learned in this manner about the consistency and nature of the lunar soil.

METEORIC PARTICLE. A small meteor, or a fragment of one.

METEORITE. A stony or metallic body that has fallen to the earth from outer space.

METEOROGRAPH. An apparatus that measures two or more meteorological elements or characteristics, as air pressure, temperature, humidity, or the like, and which automatically either records or transmits these measurements.

METEOROID. In astronomy, a generic term referring to any one of the numerous small solid bodies that plunge into the earth's atmosphere to form a meteor. The term normally refers to those bodies encountered in space outside the atmosphere and hence the implication is that these bodies, although likely to become meteors by their speed and direction of flight, have not yet made their meteoric display by entering the earth's atmosphere. (See **meteor**.)

METEOROLOGY. That branch of physics that treats of the atmosphere and its phenomena, heat and moisture changes, low and high pressures, or other such phenomena that affect the weather.

METER. (1) Any instrument or device used in a measurement. Often compounded with a prefix indicating the quantity measured, as in ammeter, voltmeter, potentiometer, etc. (2) Unit of length in metric system. (See **meter, standard**.)

METER, STANDARD. The fundamental unit of the metric system is called the meter. (See **units and dimensions**.) The original standard meter bar, known as the *mètre des archives*, was constructed of platinum in 1793. Its length at 0°C was supposedly one ten-millionth of the earth's meridian quadrant at sea level. This standard superseded an earlier provisional meter based on the length

of a seconds pendulum. In 1875 the International Bureau of Weights and Measures was established at Sèvres, France, and one of its first tasks was the construction of a new standard for the meter. The result was the *international prototype meter*, a line standard made from an alloy of 90% platinum and 10% iridium. The meter is defined as the distance between two lines on the bar when at atmospheric pressure and 0°C. A supplementary definition of the meter can be given in terms of the wavelength of the red line of cadmium in air at 760 mm pressure and 0°C, according to which 1m = 1,553,164.13 wavelengths.

METHANE. A gaseous hydrocarbon of formula, CH_4 , having a boiling point of -258°F , freezing point of -296°F , a specific gravity of 0.38, and molecular weight of 16.04 lb/mole. It has been considered as a possible rocket fuel, and it is believed that the atmospheres of Saturn, Neptune and Uranus are probably composed of it. It is non-corrosive and of low toxicity.

METHYLAL. An organic compound having the composition $\text{CH}_2(\text{OCH}_3)_2$, having a boiling point of 108°F , a freezing point of -157°F , and a specific gravity of 0.866. It has been considered as a possible rocket fuel.

METHYLAMINE. A possible rocket fuel having the chemical formula CH_3NH_2 . It has a boiling point of 20°F , freezing point of -135°F , and a specific gravity of 0.769.

METHYL ALCOHOL. An organic liquid having the chemical formula CH_3OH . It is frequently used as a rocket propellant. It has a boiling point of 150°F , freezing point of -144°F , a specific gravity of 0.795 (at 68°F) and a density of 1.11. An 80% mixture of methyl alcohol and water has a boiling point of 150°F , freezing point of -60°F , and a specific gravity of 0.873.

METRIC DATA. Those data which are obtained primarily for measurement purposes and from which a quantitative evaluation of missile performance may be made. Metric film is the film exposed for metric data purposes.

METRIC PHOTOGRAPHY. Applications of photography to measurements, e.g., to those of **photogrammetry** to determine the path of

a missile, in other words, for **trajectory data**. Metric data are usually collected with two or more cameras operating together to provide trigonometry data which then can be used to find positions with respect to time. From these successive positions, velocity and acceleration can be computed. A single camera can be used for metric purposes if it views a missile's progress with respect to accurately surveyed target screens in the field of view. Fixed-plate cameras (also ballistic cameras) or tracking phototheodolites can also be used. (See also **data reduction**.)

MEV. Abbreviation for one million electron volts, a unit of energy.

MEW. Microwave early warning radar.

M-F. Abbreviation for medium frequency.

Mg. Magnesium.

Mg. Milligram.

Mh. Millihenry.

MHE. Materials handling equipment.

MHO. A unit of **conductance**, the reciprocal of **ohm**.

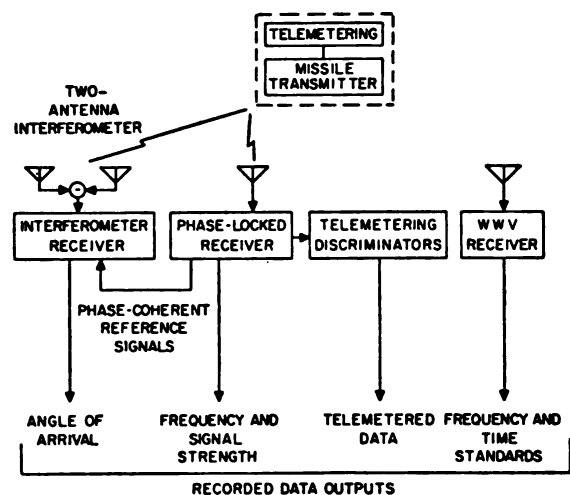
MICRO. A prefix used in the metric system to indicate one millionth part. It is abbreviated by the Greek letter *mu* (μ).

MICROBAR (DYNE PER SQUARE CENTIMETER). A unit of pressure commonly used in acoustics. One microbar is equal to 1 dyne per square centimeter. The term "bar" properly denotes a pressure of 10^6 dynes per square centimeter. Unfortunately, in acoustics the bar was used to mean 1 dyne per square centimeter. It is recommended, therefore, in respect to sound pressures that the less ambiguous terms "microbar" or "dyne per square centimeter" be used.

MICROLOCK. A satellite tracking system developed by Caltech's Jet Propulsion Laboratory for use with the U.S. Army's **Explorer** series of satellites.

The tracking mechanism employs a low power, lightweight flight transmitter in conjunction with a receiving system of advanced design. The flight transmitter radiates 3 mw for three months and provides two narrow band telemetering channels in a unit having a

total weight of 2 lb. The ground receiving equipment is capable of acquiring and tracking the beacon signal at a line-of-sight distance of 3000 miles and at any azimuth and elevation angle. Interferometer antennas are used to determine the angular position of the satellite with an accuracy of one milliradian, which is equivalent to approximately 0.04 sec in the determination of the period. (See figure.)



Microlock.

MICROMETEORITE. A meteorite so small (usually below 100 microns) that it does not give a visible track on burning in the atmosphere.

MICROMINIATURIZATION. Reduction of equipment size by orders of magnitude over sub-miniature techniques; the combining, merging, or blending of the circuit elements and the device itself.

MICRON. One thousandth part of a millimeter, thus one millionth of a meter.

MICROPHONE. A device for converting sound waves into corresponding electrical variations.

MICROPHONE, HOT-WIRE. A microphone which depends for its operation on the change in resistance of a hot wire produced by the cooling or heating effects of a sound wave.

MICROSCOPE. The optical instrument that bears this name consists essentially of two parts. (1) The objective is a lens combination, usually of small aperture and short focal

length, which forms a real, inverted, and much enlarged image of the object at a point high up in the microscope tube, very much as a stereopticon objective throws an enlarged picture upon a distant screen. The objective-lens system is composed of several positive lenses, the first of which is hemispherical with its plane surface facing the object. Following this is a larger convexo-concave or "meniscus" lens, and then two still larger plano-convex achromatic lenses. (2) The eyepiece or ocular is placed beyond, with its focal plane coinciding with this image, and acts as a collimator, so that one looking into it sees a virtual image, subtending a wide angle. The instrument is focused by varying the distance between objective and object.

A magnifier is sometimes known as a simple microscope or a pocket microscope.

MICROSECOND. A millionth of a second. The *microsecond* is a unit of time much used in radar techniques. Radar waves travel with the speed of light (186,000 miles per second, or 982 feet per microsecond). (See also **radar range measurement**.)

MICROSTRIP. In electronics, a minaturized transmission line technique used in the kilomegacycle range. It consists of a wire above a ground plane and is analogous to a two-wire line.

MICROVOLTS PER METER. The standard unit of signal strength or intensity of a transmitter, measured at some point. It is determined by dividing the receiving antenna voltage (microvolts) by the length (meters) of this antenna.

MICROWAVE. A range of frequencies in the electromagnetic spectrum; usually considered to cover the wavelength region from VHF to EHF (3 meters to 0.3 cm).

MICROWAVE AMPLIFICATION BY STIMULATED EMISSION OF RADIATION. Maser.

MIDCOURSE. (1) The portion of the trajectory of a ballistic missile, from burn-out to re-entry. (See also **launch phase** and **terminal phase**.) (2) The phase of a missile trajectory usually initiated at the end of the boost or launching phase, and ending at the start of the terminal or homing phase.

MIGHTY MOUSE. An air-to-air rocket projectile, unguided but with a proximity fuze. It was a solid fuel rocket produced by the Naval Ordnance Test Station at Inyokern, California. In the tactical version used in the early 1950's, the stabilizing fins of the Mighty Mouse folded forward on the body of the missile, and after launch, sprang backward against stops to the flight position. For this reason, the Mighty Mouse and other rockets of similar action were termed forward-firing folding fin rockets (FF-FF). Its velocity was 2,600 feet per second (Mach 2.7), its weight, 18.5 pounds (3.5 lb. warhead), its length 48 inches, and its diameter 2.75 inches. It used an "aimed" type of guidance.

MIKE. Colloquialism for microphone.

MIL. (1) A one-thousandth part of an inch. (2) The angle subtended by an arc of a circle $\frac{1}{1000}$ as long as its radius, i.e., $\frac{1}{6283}$ of 360° . (3) In U.S. Army artillery usage, the $\frac{1}{6400}$ th angular part of a circle. (4) In U.S. Army infantry usage, the angle subtended by an arc of one yard at a thousand yards range. Thus 1 artillery mil = 0.982 infantry mil. The distinction is infrequently made, and since the so-called infantry mil is always used under field conditions, the two types of Army mils are ordinarily thought of as equal. (5) In U.S. Navy ordnance usage, the $\frac{1}{1000}$ th part of a radian. (6) In electrical usage, a measure of wire diameter equal to $\frac{1}{1000}$ th inch. (See also **circular mil**.)

MIL STD. Military standard.

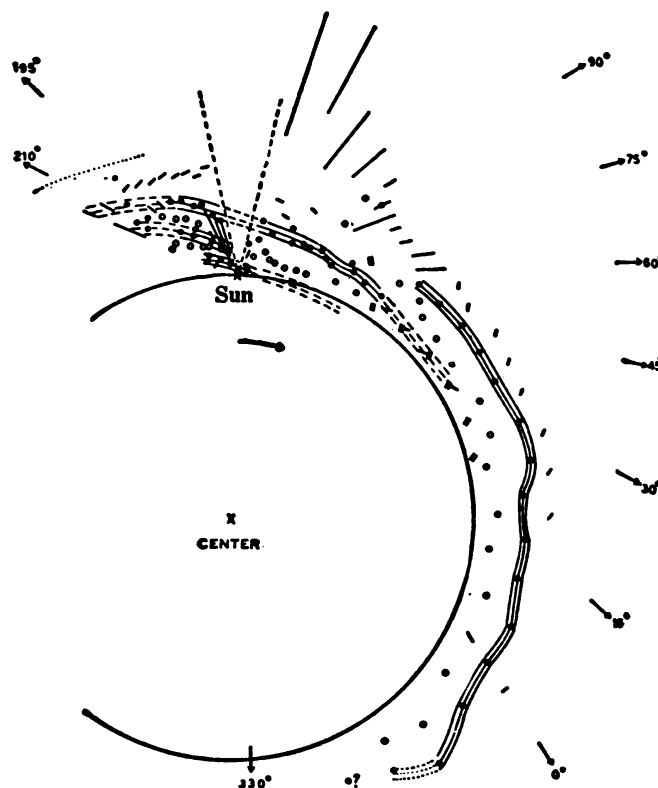
MILE. The English or statute mile of 5280' is that most commonly used by English-speaking people. This distance is supposed to be equivalent to 1000 paces of the Roman Legions stationed in Britain. Navigators and geographers prefer to use the nautical mile and the geographic mile respectively. (See **nautical mile**.)

MILESTONE. An activity or action within the research, development, test, production, and in-service life of a project. The milestone possesses a distinct, objectively identifiable, terminal point, which can be used as a means of evaluating the progress or research and development in terms of its estimated schedule.

MILKY WAY. The milky way, or galaxy, appears to the naked eye as a broad irregular band of misty light which encircles the sky. The telescope shows that it is in reality made up of myriads of faint stars interspersed with gaseous **nebulae**. Its light is due to these faint stars, and if all of the stars which can be distinguished as individuals with the unaided eye were blotted out, the milky way would still remain undiminished in intensity against the otherwise dark sky. A mere casual examination of the milky way on a dark night will reveal that its intensity varies from point to point, which is an indication that the faint stars are not uniformly distributed. The first line of attack on the general problem of the distribution of matter in space was made by Sir William Herschel, in 1784. His method, which is essentially that of the modern methods of star counting, consisted in counting the number of stars visible in his telescope when it was directed to various directions in the sky.

In addition to the study of the Milky Way structure by star counts, many other methods of investigation have been developed and research is going forward. The existence of absorbing material in "empty space" has been confirmed from a variety of observations. We have even been able to make approximate determinations of the character and density of this "cosmic dust" or "cosmic haze," to mention merely two of the various descriptive terms applied to it. We are confident that it is not uniformly distributed and that there exist large, and relatively dense, clouds of dark material known as dark **nebulae**. Until the effects of this material on star counts and other data, in all directions and distances from our sun, have been established, we cannot do much more than guess as to the size and detailed structure of the Milky Way. All that we are justified in stating is that the stars of the galaxy are assembled mainly in a thin disk (about 80,000 light years in diameter) about a thicker central region, and that the sun's place in the disk is of the order of magnitude of thirty thousand light years from the center. The total mass of this galactic system is probably as high as two hundred billion (2×10^{11}) times the mass of our sun.

The methods of **radio astronomy** have yielded considerable additional information about the galactic system, disclosing spiral



Part of a spiral arm of the galactic system. Traced with the 21-cm hydrogen line. (Diagram by C. A. Muller, H. C. van de Hulst, and J. H. Oort, Leiden Observatory.)

arms of great extent, in one of which the sun may be located.

The problems relating to the dynamics and evolution of this galactic system are far from definitive solution. We have an abundance of evidence, from an analysis of the observed stellar motions, that the Milky Way is in general rotation with a period of the order of two hundred million years. Questions as to whether or not this motion is uniform, the location of the axis of rotation, etc., are far from being definitely answered.

MILLI- A prefix used with many physical units, denoting one one-thousandth. Thus 1000 millimeters = 1 meter, 1000 milliamperes = 1 ampere.

MILLIBAR. One thousandth of a bar. It is a unit of pressure used in meteorology. The normal pressure at sea level is 29.92 inches and is equivalent to 1013 mb. One mb is equivalent to 0.0295 in. of mercury at 32°F under standard conditions of gravity.

MILLISADIC. The trade name for Consolidated Electrodynamics Corporation high-

speed analog-to-digital data processing system.

MILITARY GRID REFERENCE SYSTEM (MGRS). The standard map coordinate system adopted by the U.S. armed forces to accommodate all points on the earth's surface in a single system of reference. It is used with the Universal Transverse Mercator Grid (UTM). The military grid is composed of the polar stereographic grid system and the transverse mercator grid. The polar areas are taken as separate problems and are shown on a different projection than the remainder of the earth. The origins of the UTM are the prime meridian and the equator. From these origins the earth's surface is divided into strips six degrees wide lying between 80°N and 80°S latitude. Each of these strips is called a UTM zone. Each grid zone is further subdivided into grid zone designations, which are themselves further divided into 100,000 meter squares. The grid zone is 6° wide and 8° long. Using the MGRS, each 100,000 meter square is given a letter pair designation which identifies it within the particular grid zone.

MILS. *Missile impact location system.*

MINER'S FUSE. *Bickford fuse.*

MINIATURIZATION. Usually, the reduction in size, weight, or both of a system, package, component or element by using very small parts and interconnections. Sometimes, the addition of a capability, increased power, better performance, etc. for the same size or weight. (See *subminiaturization*.)

MINIJET. A trade name for a commercially available small-size powder rocket for use by amateurs or experimenters.

MINIMAL FLIGHT PATH. The flight path between two points that affords the shortest possible time enroute. For aircraft the minimal flight path may be planned to take advantage of winds and pressure systems, and is thus not necessarily the shortest flight path between two points.

MINIMAX. *Saddle point.*

MINITRACK. A sub-miniature radio transmitter capable of sending data over 4000 miles on extremely low power. Minitrack was designed by the U.S. Naval Research Laboratory for use with the *Vanguard* Project as a means for determining satellite position, and also transmitting limited *telemetering* information back to earth. Very sensitive radio receivers scattered around the earth lock onto the minitrack signal. A phase comparison technique permits accurate angular determinations at each station. The transmitter can be fitted into a cylindrical container 5 inches long and 3 inches in diameter, with a total weight of 13 ounces. Its power is 10-50 milliwatts on 108 megacycles per second. Its detector is a single-stage, crystal-controlled oscillator using one *transistor*. Its power supply comprises 7 small 1.2 volt mercury batteries.

MINOR CYCLE. In a digital computer using serial transmission, the time required for the transmission of one word, including the space between words.

MINUTE. (1) Unit of time, abbreviation m or min. One 1440th part of a mean solar day; 60 seconds. (2) Unit of angle, abbreviation '. One 60th part of a degree.

MINUTEMAN. A U.S. Air Force ICBM, announced in 1958. Its initial design called for a flexible two or three stage all-solid propellant configuration suitable for either IRBM or ICBM flights. Nose cone development was assigned to Avco, guidance to North American Aviation, with Thiokol Chemical Corporation as prime contractor for the first stage, and Aerojet General Corporation acting as back-up source; Thiokol and Aerojet carrying out parallel programs for the second stage, and Aerojet taking prime contract for the third stage, with Thiokol providing back-up. As the name implies, readiness for prompt firing is an important feature.

MIRAN. *Missile RANging.*

MIRAN. A type of microwave position measuring system installed at Holloman Air Force Base, New Mexico. It was formerly known as the "beacon triangulation system." It is an omnidirectional, pulse-type system, measuring range only. It uses a master interrogator, a missile beacon, and two or more slave stations on the ground. Each slave station measures the pulse transit time, and these are displayed on oscilloscopes at the master station and continuously filmed for post flight evaluation. Missile position can be determined by the intersection points of simultaneous range determinations. Instantaneous missile positions can be found by use of a *computer*, for real time display.

MISALIGNMENT, ANGULAR THRUST. *Angular thrust misalignment.*

MISALIGNMENT, FIN. *Fin misalignment.*

MISALIGNMENT, LINEAR THRUST. *Linear thrust misalignment.*

MISFIRE. An unsuccessful attempt to start a rocket motor; usually, but not always, a case in which the igniter functions properly but the propellant does not ignite (or does ignite but goes out).

MISS DISTANCE. (1) The closest distance between two objects having relative motion; e.g., a guided missile intercepting a target. (2) The great-circle distance between the observed impact point and the intended impact point.

SOME CHARACTERISTICS AND FEATURES OF U.S. GUIDED MISSILES

Category	Nomenclature		Basic Data			Physical Data				Performance		Status as of Jan. '58			Remarks
	Name	Designation	Prime Contractor or Manufacturer	Powerplant Type and Manufacturer	Guidance Type and Manufacturer	Weight at Take Off	Length, Less Booster Ft.	Body Diameter, Ft.	Span of Wings or Fins, Ft.	Approximate Maximum Range, Mi.	Approximate Maximum Mach Number	Research	Development	Production	
I(A) Air-to-Air	Falcon	GAR-1 GAR-2A	Hughes	1 Thiokol spr	Radar Infrared	110	6				su	x	x	x	Armament for Convair F-102
	Genie (Ding Dong) (High Card)	MB-1	Douglas	1 A-G spr	Unguided						su			x	Nuclear warhead
	Sidewinder	AAM-N-7	Philco	1 ABL spr	Infrared homing (Philco, G.E.)	155	9	4.5						x	50,000 ft. alt.
II(A) Air-to-Surface	Sparrow 1	AAM-N-2	Sperry/Douglas	1 A-G spr	Beam Rider (Sperry)	300	12.5			3				x	Plased out
	Sparrow 2	XAAM-N-3	Douglas		Radar								x		Experimental
	Sparrow 3	XAAM-N-4	Raytheon		Radar (Raytheon)	350	12			6		x	x		
	Bull Pup	XASM-N-7	Martin	1 A-G spr	Optical (Martin)	540	11						x		Canard Airframe
	Dove	ASM-N-4 & 5	East. Kodak		Optical (East. Kodak)									x	
II(B) Air-to-Under water	Rascal	GAM-63	Bell	3 Bell lpr	Command (Bell)			48"		100	1.5			x	B 47; Armament
	Petrel	AUM-N-2	Fairchild	1 J44 tj	Radar	3,800	24		13		0.7			x	Launched from Patrol Aircraft—Phased out
III Surface-to-Air	Bomarc	IM-99	Boeing	2 Mar. ri. & 1A-G spr booster	Command & Radar	15,000	47		18					x	60,000' alt. capability; nuclear warhead
	Hawk		Raytheon/Northrup	1 Thiokol spr	Radar homing		17	14"						x	Low angle anti-aircraft coverage
	Nike I—Ajax	SAM-A-7	West. Elec./Douglas	1 A-G lpr; AG spr booster	Radar Command (West. Elec.)	1,000	20	1		20	2			x	Conus Defense
	Nike B—Hercules		West. Elec./Douglas	1 A-G spr; 4AG spr booster	Radar Command (West. Elec.)		27						x		Nuclear warhead

SOME CHARACTERISTICS AND FEATURES OF U.S. GUIDED MISSILES (Cont.)

Nike—Zeus		Army- Ord.	BTL/ Douglas		Radar						x	x	Anti-ICBM
Talos	XSAM-N-6; IM-70	BuOrd & Army Ord.	Bendix M/ McDonnell	Bx/McD rj; ABL spr booster	Radar	3,000	20	30"				x	One version carries nuclear warhead. APL/JHU Devel. Cruiser Defense; Land Defense (RCA Respon.)
Tartar		BuOrd	Convair	1 ABL spr	Beam Rider (Philo; BxP)		20				x	x	Destroyer Anti-aircraft DDG Class
Terrier 1	SAM-N-7	BuOrd	Convair	1 ABL spr ABL spr booster	Beam Rider (BxP)	3,000	15					x	50,000' ceiling
Wizard		USAF	Convair/ RCA								x		Anti-ICBM
Dart		Army- Ord.	ADC/CW; UB	1 GC spr								x	Anti-tank
Honest John		Army- Ord.	Douglas/ Emerson	1 Herc. spr	Unguided							x	Long-range artillery; nuclear warhead
Lacrosse		Army- Ord.	Martin	1 Thiokol spr	Command (Martin)							x	CAL Development; close support missile
Little John		Army- Ord.	Douglas/ Emerson	1 Herc. spr	Unguided						x		Short-range Honest John
Atlas	ICBM-XSM-65 (WS 107A-1)	USAF	Convair	NAA lpr	Radar				5,500	10+	x	x	Intercontinental ballistic missile; nuclear WH; G.E. Nose Cone
Corporal II	XSSM-A-17	Army- Ord.	Firestone/ Gilfillan	1 JPL lpr	Radar				75	3		x	Developed at JPL; nuclear warhead; ballistic trajectory
Jupiter	IRBM	Army- Ord.	Chrysler	1 lpr NAA					1,500		x	x	Intermediate range ballistic missile; nuclear warhead
Matador	TM 61 A, C, D	USAF	Martin	1 All. J33-A-37 tj; 1 Thiokol spr	Ground controlled		39.5		28.8	600	0.9	x	35,000' alt. capability; nuclear warhead
Mace	TM76A(61B)	USAF	Martin	tj; spr	Self-contained					600	0.9	x	40,000' alt. capability
Navaho	XSM-64	USAF	No. Amer.	2 Wr. rj; NAA lpr booster	Inertial (NAA)					5,500	3	x	Three versions planned; program cancelled
Pershing		Army- Ord.		spr								x	Replacement for Redstone

SOME CHARACTERISTICS AND FEATURES OF U.S. GUIDED MISSILES (Cont.)

Nomenclature			Basic Data			Physical Data				Performance		Status as of Jan. '58			Remarks
Category	Name	Designation	Prime Contractor or Manufacturer	Powerplant Type and Manufacturer	Guidance Type and Manufacturer	Weight at Take Off	Length, Less Booster Ft.	Body Diameter, Ft.	Span of Wings or Fins, Ft.	Approximate Range, Mi.	Approximate Maximum Mach Number	Research	Development	Production	Service Use
IV(B) Surface-to-Surface (Long Range) (cont.)	Polaris	IRBM	Lockheed	A-G spr	Inertial (G.E.)					1,500		x	x		Fleet ballistic missile; nuclear WH
	Redstone		Chrysler	1 NAA lpr						175			x	x	
	Regulus I	SSM-N-8	Chance Vought	1 All. J33-18A tj; 2 A-G spr	Inertial (Sperry)					500	0.9			x	
	Regulus II		Chance Vought	tj; 2 spr	Self-contained	14,000	30	4.5		1,000	2		x	x	Nuclear WH; 50,000 ft. altitude
	Sergeant		JPL/Sperry	1 Thiokol spr			20						x	x	Corporal replacement; ballistic trajectory
	Snark	SMI-62	Northrup	1 P & W J-57 tj; 2 A-G spr	Self-contained (Northrup)					5,000				x	Nuclear WH
	Thor	IRBM-XSM-75 (WS 315A)	Douglas	1 NAA lpr	Inertial (A C Spark Plug)					1,500	5+		x	x	Intermediate Range Ballistic missile, nuclear WH; G.E. Noos Cone
	Titan	ICBM-XSM-68 (WS 107A-2)	Martin	A-G lpr	Self-contained					5,500	15+		x		Intercontinental ballistic missile; nuclear WH; AVCO Noos Cone
	Triton		McDonnell	McD rj; ABL spr booster							3	x	x		APL/JHU Devel.; Program suspended

SOME CHARACTERISTICS AND FEATURES OF U.S. GUIDED MISSILES (Cont.)

V Research	Aerobee	V-A-1A	USAF; Navy Signal Corp.	Aerobee/ Cooper Develop- ment	1 A-G lpr	1,140	20.0	1.3	5.2	4.8	x	370,000' ceiling; 3 fins
	Aerobee-Hi	AJ11-6 AJ 11-18	USAF; NAVY	Aerobee	1 A-G lpr	1,310	31	1.3	5.2	6.5	x	820,000' ceiling; 3 fins- payload 130f
	ASP			GC	1 GC spr	245	12	0.5		5	x	175,000' ceiling; 3 fins
	Explorer I (1958 Alpha)	Jupiter "C"	Army- Ord.		1 lpr; 3 stages spr						x	Satellite (31 lb.)
	HTV-Hypersonic Test Vehicle		USAF	ADC	spr							Used for Aerothermodyno. research
	Terrapin			Univ. of Md.							x	
	Oriole			Univ. of Md.							x	120 mile alt. max.
	Vanguard		BuAer	Martin	1st Stage GE lpr, 2nd Stage A-G lpr, 3rd Stage GC spr	2,200	72'	3.9				Earth Satellite; Payload 21.5f
	Viking		NRL	Martin	1 RMI lpr						x	14 built-alt. test vehicle
	Waap				1 GC spr							Adopted from Loki 110,000-150,000 Ionosphere research
	X-7		USAF	Lockheed	Mar ri					3	x	Exp. test bed
	X-17		USAF	Lockheed	3 Stage; Thiokol spr	12,000	40					Re-entry test vehicle; Payload 70f

ABBREVIATIONS USED IN FOREGOING TABLE

ADC—Aerophysics Development Corp; Curtiss Wright	JPL—Jet Propulsion Lab; Cal. Tech.
A-G—Aerojet-General Corp.	Lyc—Lycoming Div. of AVCO
All—Allison Division	Mar—Marquardt Aircraft Co.
APL/JHU—Johns Hopkins Univ., Applied Physics Lab.	McC—McCulloch Motors
Army-Ord—Army Ordnance	NAA—North American Aviation, Inc.
BM—Bendix-Mishawaka	NRL—Naval Research Lab.
BP—Bendix-Pacific	P & W—Pratt & Whitney Aircraft Div.
BTL—Bell Telephone Laboratories	RMI—Reaction Motors, Inc.
BuAer—Navy Bureau of Aeronautics	RRU—Remington-Rand Univac
BuOrd—Navy Bureau of Ordnance	SigCor—Signal Corps, Dept. of Army
BUR—Burroughs	Sperry—Sperry Gyroscope Co.
CAL—Cornell Aeronautical Laboratory	Thiokol—Thiokol Chem. Corp.
Con—Continental Motors Corporation	UB—Utica-Bend
CV—Chance Vought	USAF—United States Air Force
CW—Curtiss Wright	Wstghse—Westinghouse Electric
Emer—Emerson	
Fair—Fairchild-Engine Division	lpr—Liquid Propellant Rocket
Ford—Ford Instrument Co.	rj—Ramjet
GC—Grand Central Rocket Co.	spr—Solid Propellant Rocket
G.E.—General Electric	su—Supersonic
Herc—Hercules Powder Co.	tj—Turbojet
	*—Obsolete Program or Programs Cancelled Prior to 1957 are not included.

MISS DISTANCE INDICATOR. (1) A type of camera equipment trained on the target area which gives a record of the **miss distance** of a projectile or missile. (2) An electromagnetic device for measuring and displaying or recording **miss distance**.

MISSILE. (1) Any object thrown, dropped, projected, or propelled, or designed to be thrown, dropped, projected, or propelled, for the purpose of making it damage a target. (2) A **guided missile**.

"Missile" is sometimes used as a term of convenience to designate any projectile, whether sent at a target or not. While this is a normal extension of the term, this usage is largely confined to journalistic or popular speech, and cannot be said to constitute good usage.

MISSILE, AIR-TO-AIR (AAM). A guided missile which can be launched from one aircraft against another. Passive or active guidance may be used. U.S. types are usually named for birds: e.g., Falcon, Sparrow. (See **Missile, Guided; Model Designation**.)

MISSILE, AIR-TO-GROUND (AGM). A guided missile with or without a propulsion system which can be launched from an air-

craft against a surface target. Categories include air-to-ground and air-to-underwater types. (See **Missile, Guided; Model Designation**.)

MISSILE, AIR-TO-SURFACE (ASM). **Missile, Air-to-Ground; Missile, Guided; Model Designation.**

MISSILE ATTITUDE. The orientation of a **guided missile** as determined by the inclination of its **axes (roll, pitch, and yaw)** in relation to the earth or fixed space.

MISSILE, BALLISTIC. (1) Any missile guided especially in the upward part of its trajectory, but becoming a free-falling body in the latter stages of its flight through the atmosphere. (2) A missile which depends primarily upon momentum rather than aerodynamic forces for the determination of its trajectory.

MISSILE, FLEET BALLISTIC (FBM). **FBM (Fleet Ballistic Missile).**

MISSILE, GROUND-TO-AIR (SURFACE-TO-AIR). A missile launched from the surface (ground or ship) for the purpose of intercepting an airborne vehicle (e.g., airplane, missile). (They are generally used for anti-

aircraft defense and may be of a short or long range type.) U.S. types are usually named from mythological terms (e.g., Nike, Talos).

MISSILE, GROUND-TO-GROUND (SURFACE-TO-SURFACE). A missile launched from the surface (land or sea) against surface targets. Two further categories are used. They depend on (a) whether the missile is to be used for a long-range type of offense (e.g., Matador, Snark, ICBM, IRBM, Regulus, etc.), or (b) whether it is of the much shorter-range type used for support of ground troops (e.g., Dart, Corporal, Sergeant, etc.).

MISSILE, GUIDED. An unmanned vehicle moving above the earth's surface, whose trajectory or flight path is capable of being altered by a mechanism within the vehicle. One classification system in current use is:

Surface-to-Surface—missiles may be launched from ground stations on ships against ground installations, surface vehicles, or surface ships. (See **missile, ground-to-ground**)

Surface-to-Air—missiles may be launched against airborne aircraft, airships, or guided missiles. (See **missile, ground-to-air**) Similar variations of the other classifications exist; however, the words surface and air are governing. (See **model designation**.)

The most important current U.S. guided missiles are tabularized on Pages 390-393.

MISSILE, GUIDED BALLISTIC. A ballistic missile which is guided during the powered portion of the trajectory and utilizes a free ballistic path during a portion of its flight.

MISSILE IMPACT LOCATION SYSTEM. A splash net system using hydrophones.

MISSILE—Inter-Continental Ballistic Missile—(ICBM). A missile flying a ballistic trajectory after guided powered flight, usually at velocities in excess of 20,000 feet per second and capable of operating over ranges in excess of 3500 nautical miles.

MISSILE—Intermediate Range Ballistic Missile—(IRBM). A generic term defining a missile flying a ballistic trajectory after guided powered flight and capable of a range of 800 to 1,500 nautical miles.

MISSILE LEAD-ANGLE. The angle between the flight path of a missile on a collision

course with a target and the interconnecting line-of-sight.

MISSILE MASTER. An electronic system of computers, communications equipment and data processing and transmission equipment developed by the Martin Company for the U.S. Army Air Defense Command. The first experimental installation was made at Fort Meade, Maryland, for the Army's Antiaircraft Command. This system collected data on approaching aircraft from all available sources, collated it, distinguished enemy aircraft, selected targets, and directed the fire of individual missile batteries which it supervised—all automatically.

MISSILE, OPERATIONAL. Operational missile.

MISSILE RANGE. A marked-off course over which test missiles are flown under observation.

MISSILE RANGING (MIRAN). A multi-station measuring system using pulse radar triangulation techniques for measurement of range.

MISSILE RESPONSE. The time interval between generation of a guidance signal and initiation of a maneuver to correct the causative error.

MISSILE RETAINER. Tail grab.

MISSILE ROLL RANGE. The angle through which the missile can be controlled in roll. It determines the azimuth range of the targets that can be attacked without rotating the launcher.

MISSILE SERVICING TOWER. A superstructure providing personnel platforms for missile fueling and servicing.

MISSILE STORAGE STRUCTURE. The structure and facilities necessary to receive, support, store and service one or more missiles.

MISSILE STOWAGE SUPPORTS (NAVAL). Supports provided within the missile magazine to secure the missile radially at the hard points and prevent excessive sway while being transported at sea.

MISSILE, STRATEGIC. Model Designation; Strategic Missile.

MISSILE, SUB. Sub-missile.

MISSILE, SURFACE-TO-AIR. Missile, Ground-to-Air; Missile, Guided; Model Designation.

MISSILE, SURFACE-TO-SURFACE. Missile, Ground-to-Ground; Missile, Guided; Model Designation.

MISSILE, SURFACE-TO-UNDERWATER. Missile, Ground-to-Ground; Model Designation.

MISSILE SYSTEM, GUIDED. (1) The guided missile itself including all airborne systems (Preferred). (2) A combination of a guided missile and its ancillary launching, external guidance, test and handling equipment which together accomplish a mission. E.g., destruction of a target. (See **weapon system**.)

MISSILE, UNDERWATER-TO-AIR. Missile, Ground-to-Air; Model Designation.

MISSILE, UNDERWATER-TO-SURFACE. Missile, Ground-to-Ground; Model Designation.

MISSILE UNIT. A military unit made up of persons with the skills required to service, make ready, or launch guided or ballistic missiles, or to train others to do so.

MISSILRY. The art or science of designing, developing, building, launching, directing, and sometimes guiding a rocket missile; any phase or aspect of this art or science.

MISSION. The end objective of a military operation; the objective may be tactical or strategic.

MITCHELL CHRONOGRAPH. A type of motion picture camera (35mm), equipped with a sweep-second stop-watch which is photographed in the corner of each frame of the film to provide timing. This camera is usually located behind the launch pad, near the backward extension of the flight line and locked in azimuth. When the missile is fired, it is manually tracked in elevation. The angular distance of the missile from a vertical plane can thus be measured on the developed film.

MITCHELL PHOTOTHEODOLITE. An instrument used for obtaining missile flight path data. It consists of a Mitchell 35mm camera of adjustable frame rates, with a telescopic lens of approximately one-foot focal length. The camera usually takes 24 frames per second, recording observation data on each frame. Accuracy is approximately 1 mil. Ballistic missiles of the V-2 type have been tracked to a distance of 25 miles with this equipment. Such cameras are normally placed on a base line and used photogrammetrically (in pairs).

MIXER. The first detector in a **superheterodyne** receiver.

MIXING RATIO. In the atmosphere, the ratio of water vapor to dry air expressed in kilograms of water per kilogram of air.

MIXTURE RATIO. In propulsion, the ratio of oxidizer to fuel used in a unit time, measured by weight (W_o/W_f).

MIZAR. Mizar (ζ Ursae Majoris) is, perhaps, the most interesting star in the "big dipper." It is probably the first **double star** ever observed. The fourth magnitude star Alcor forms with it a naked-eye double, and Mizar itself has a close companion which is telescopically visible. It was the first star observed as double by Riccioli in 1650. Tradition says that observation of the pair Mizar-Alcor was considered a good test of eyesight among the American Indians. If this was a difficult pair for them to separate, their eyesight could not have compared very favorably with that of modern times, for it is an easy double for most people.

As well as being the first visual double star to be discovered, Mizar also has the distinction of being the first spectroscopic binary discovered. In 1889 E. C. Pickering discovered that the spectral lines of this star were alternately double and single, a phenomenon which can only be adequately explained if the star is a close binary. In 1908 the fainter companion of Mizar and also the more distant, bright companion Alcor were both found to be spectroscopic binaries.

ml. Milliliter.

mm. Millimeter.

Mn. Manganese.

Mo. Molybdenum.

MOBILE STATIONS. A missile launch complex designed for mobile use in forward combat areas for defense against aircraft or for attack on enemy ground targets.

MOBILITY. (1) Random motion of various particles, such as sub-atomic particles, atoms, ions, molecules and colloidal particles. (2) Directed motion of charged particles subject to the action of forces and fields of force. Hence, the term mobility applies to all processes of electrical conduction, whether by ions, by electrons, by "holes," etc. The mobility, μ , is given by the expression

$$\mu = \frac{\sigma}{ne}$$

where σ is the conductivity, e is the charge of the carriers, and n is their number-density. The mobility is, therefore, expressed in cm/sec per volt/cm, or in similar units, and it gives the drift velocity of the carriers under the influence of a unit electric field.

MOBILITY ANALOGY. An acoustical-mechanical dynamical analogy in which velocity corresponds to a voltage and force corresponds to a current. (See **mechanical rectilinear impedance**.)

MOC. Master operational controller.

MODE. (1) In statistics, the most frequently occurring value of a population. (2) In microwave transmission, the characteristics of the electric and magnetic fields of a wave as it is transmitted through a waveguide. (3) In radar, the manner of tracking. Tracking modes can be "manully" "aided" or "automatic." Manual tracking involves manipulation by the radar operator of controls to cause the radar to follow the target in range, azimuth and elevation. He adjusts these controls proportionately to the motion of the target. Aided tracking adds further control devices, so that the operator is required only to set rates of motion into his equipment. As long as the target continues at a constant rate, no further adjustment is necessary. Automatic tracking is a mode in which all control necessary to keep the radar on target is accomplished by closed loop servomechanisms in the radar circuits. Once the radar is locked onto target, the operator need make

no adjustments. In airborne intercept radars a "search" mode, in which a large volume ahead is scanned, is first used to acquire a target. Thereafter the radar is locked on and a "track" mode ensues.

MODE, PI. In a **magnatron**, the mode of resonance oscillation in which the phase difference between any two adjacent anode segments is π radians.

MODE, TE. Any mode of microwave propagation in a wave guide or between parallel plates, in which the electric field is wholly transverse to the direction of propagation. The $TE_{1,0}$ mode is commonly used in rectangular wave-guide transmission lines.

MODE, TEM. A mode of microwave propagation between parallel plates (or in a coaxial transmission line), in which the electric field is everywhere perpendicular to the conductors and the wave length is independent of the spacing between them.

MODE, $TEM_{0,1}$. A mode of microwave propagation which has axial symmetry if excited in a circular wave guide.

MODE TRANSDUCER. A device for transforming an **electromagnetic wave** from one mode of propagation to another.

MODEL ATMOSPHERE. Atmosphere, model.

MODEL DESIGNATION FOR MISSILES. A formal designation for a missile assigned by the U.S. government. One system among others, in current use is:

AAM	Air-to-Air Missile
ASM	Air-to-Surface Missile
AIM	Air-to-Underwater Missile
GAM	Guided Aircraft Missile
SAM	Surface-to-Air Missile
SM	Strategic Missile
SSM	Surface-to-Surface Missile
SUM	Surface-to-Underwater Missile
UAM	Underwater-to-Air Missile
USM	Underwater-to-Surface Missile

Preceded by I for Development Missiles
Preceded by Y for Service Test Missiles

Followed by —N for Navy Missiles
—A for Air Force Missiles
—G for Army Missiles

Followed by —odd numbers for Navy Missiles
—even numbers for Air Force Missiles. (See **Missile, Guided.**)

MODEL SPECIFICATIONS. A formal specification defining the characteristics of a particular missile, system or subsystem model. The specification may be an equipment rather than performance type, but includes design and test criteria. Model specifications are usually prepared by the contractor as a contractual requirement.

MODEL TYPES. (1) Research Model: Includes any one or all of the following: breadboard model and development model.

- (a) Breadboard Model: An assembly of parts and/or components to test the feasibility of a proposed design. Usually electrical or electronic.
- (b) Development Model: A model used to develop and/or perfect the proposed design of a component, subsystem or system. Usually nonelectrical.
- (c) Mathematical Model: A mathematical representation of a missile and/or its system and components which can be used to predict performance.

(2) Prototype Preproduction Model: A model suitable for evaluation of mechanical and electrical form, design and performance. It approaches final mechanical and electrical form, employs approved parts, or reasonable equivalent, and is representative of final equipment.

(3) Production Model: This is equipment in its final mechanical and electrical form, of final production design and made by production tools, jigs, fixtures, and methods.

MODERATOR. A substance, such as graphite or heavy water, used in a **nuclear reactor** to slow down neutrons from the high energies at which they are released in fission to lower energies at which they cause fission more readily.

MODIFICATION. A major or minor change in the design of an adopted item or material which is effected in order to correct a deficiency, facilitate production, increase reliability or performance, or to improve operational effectiveness.

MODULATED WAVE. A wave, some characteristic of which varies in accordance with the value of a **modulating wave**.

MODULATING WAVE. A wave which causes a variation of some characteristic of the **carrier**.

MODULATION. The process or result of the process whereby some characteristic of one wave is varied in accordance with another wave. In radio communications, the modulated wave is called the **carrier**, and the other wave is called the **modulating wave**. By extension, the term modulation is applied to any process that varies a characteristic of the carrier.

MODULATION, AMPLITUDE. A method of modulating a radio-frequency carrier by causing the amplitude of the carrier to vary above and below its quiescent value in accordance with the audio or other signal to be transmitted. The frequency of the carrier remains constant. Commonly abbreviated as AM.

MODULATION, CROSS. A type of intermodulation due to **modulation** of the **carrier** of the desired signal by an undesired signal.

MODULATION, DOUBLE. A modulation system in which the modulating signal is used to modulate a **sub-carrier**. The modulated sub-carrier is used in turn to modulate a **carrier**.

MODULATION, DUAL. The **modulation** of a single carrier by two methods (such as **amplitude-** and **frequency-modulation**) simultaneously.

MODULATION FACTOR. The ratio of the maximum departure, either positive or negative, of the modulated wave, from its modulated value to its unmodulated value. It is also called modulation index.

MODULATION, FREQUENCY. A method of modulating a radio-frequency carrier by causing the frequency of this carrier to vary above and below the quiescent value, at a rate determined by the audio or other modulating signal to be transmitted. The amplitude of the carrier remains constant. Commonly abbreviated as FM.

MODULATION NOISE. Noise, modulation.

MODULATION, PHASE. A method of modulating a carrier-frequency current by causing the phase of the modulated signal (with respect to the unmodulated carrier) to vary from instant to instant in accordance with the audio frequency or other modulation signal. As in frequency modulation, the power output of the transmitter is constant at all times.

MODULATION, PULSE. A method of modulating an RF carrier by pulsing it periodically by one or more pulses. Abbreviated as PM.

MODULATION, PULSE DURATION. Telemetry, pulse duration modulation.

MODULATION, PULSE FREQUENCY (PFM). A form of pulse time modulation (see **modulation, pulse time**) in which the pulse repetition rate is the characteristic varied. A more precise term for "pulse frequency modulation" would be "pulse repetition-rate modulation."

MODULATION, PULSE POSITION. A form of pulse time modulation (see **modula-**

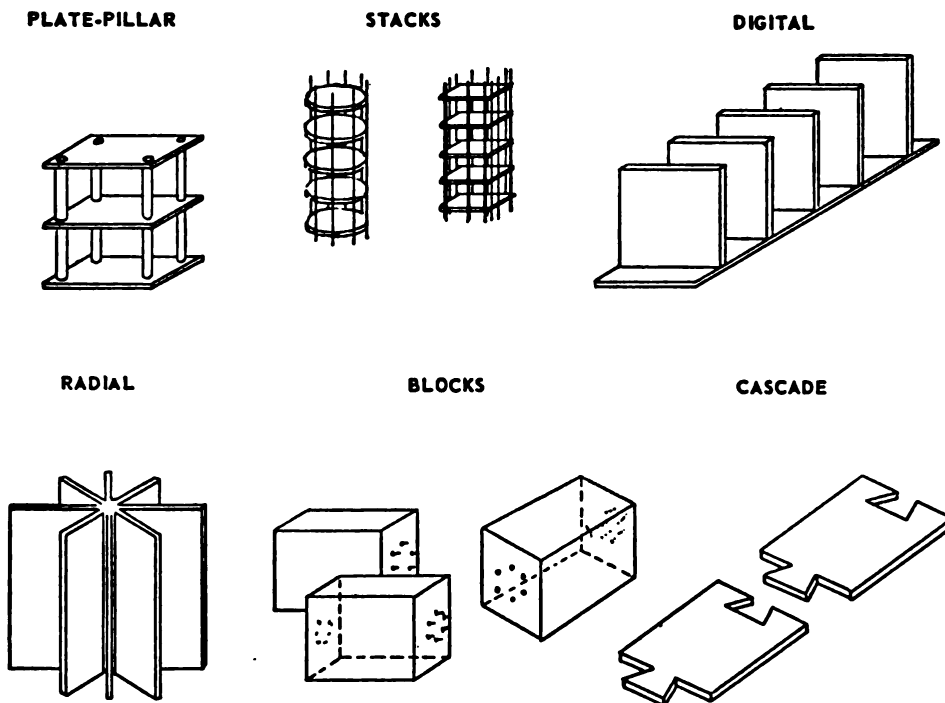
tion, pulse time) in which the instantaneous sample of a modulating wave controls the time position of a pulse in relation to the timing of a recurring reference pulse.

MODULATION, PULSE TIME. A method of modulating a radio frequency carrier by pulsing it periodically with a reference pulse followed by timed pulses to convey information. Abbreviated as PTM.

MODULATION, PULSE WIDTH. Telemetry, pulse width modulation.

MODULATOR, DOUBLE-BALANCED. Ring modulator.

MODULE. (1) As used in the automation and electronics field, a single assembly of parts and/or components to form a larger component which meets a functional requirement by performing all of the resistive, inductive and capacitive functions of a vacuum tube circuit. (2) A combination of components within a package, or so arranged that they are common to one mounting, that provide a complete function or functions necessary for sub-system or system operation. (See figure.)



Components and parts are surface or volume mounted. The modules are replaceable as a unit. Form selected is a function of application, space available, heat dissipation required and environment.

Typical modular form factors.

MODULUS. A proportionality constant in the form of a number or coefficient that denotes the measure of a property of a material, function, force or other physical quantity. Examples are the **shear modulus**, and the **modulus of elasticity** (**Young's modulus**).

MODULUS OF ELASTICITY. The ratio, within the limit of elasticity, of the stress to the corresponding strain. The stress in pounds per square inch is divided by the elongation in fractions of an inch for each inch of the original gauge length of the specimen.

MODULUS OF RESILIENCE. Resilience, modulus of.

MOLE. In chemistry, a mole weight, that is the number of unit weights of a substance equal in number to its molecular weight. (In the cgs system, one mole is the weight in grams equal to the molecular weight.)

MOLECULAR BEAM TUNNEL. A wind-tunnel used in the study of superaerodynamics. It operates at extremely low pressures (down to one ten-millionth of an **atmosphere**).

MOLLIER DIAGRAM. The properties of a vapor, as recorded in vapor tables, may be displayed graphically in a number of ways among which the mode used, and probably the most valuable, is the charting upon a plane whose coordinates are **enthalpy** or total heat and **entropy**. Generally, the total heat is made the **ordinate**, and entropy the **abscissa**. This chart of the properties of vapor is named the Mollier Diagram, and is of considerable use in tracing both theoretical and actual expansions of vapor. A throttled expansion on the Mollier Diagram is parallel to the constant heat lines, and adiabatic expansion is parallel to the constant entropy lines. Pressure, quality or superheat, and total temperature are shown on the Mollier Diagram as series of lines curved and inclined to the axes. Thus all characteristics of a vapor except volume may be displayed on the Mollier Diagram.

MOLYBDENUM. Metallic element. Symbol Mo. Atomic number 42.

MOMENT. (1) The tendency of a force to produce rotation in the system in which it is operating. The moment of a force is equal to the magnitude of the force multiplied by the

perpendicular distance of its line of action from the axis of rotation of the system. This is known as **torque** or the first moment. It can be represented by a vector whose magnitude is equal to the product of the force magnitude and the perpendicular distance to the axis; the direction of the moment vector is the direction which a right hand screw would advance if turned by the force. (2) In aerodynamics, there are three moments: pitching, rolling, and yawing. Moments may also be named by the effect they are intended to achieve, e.g., restoring moment or damping moment.

MOMENT COEFFICIENT. Aerodynamic coefficients.

MOMENT OF INERTIA. Inertia, moments and products of.

MOMENTUM. For a single particle of mass m whose position vector is \mathbf{r} the momentum is the vector quantity

$$m \frac{d\mathbf{r}}{dt} \text{ or } m\mathbf{v}, \text{ where } \mathbf{v} = \frac{d\mathbf{r}}{dt}$$

is the velocity. For a system of n particles of masses $m_1 \cdots m_n$ respectively and position vectors $\mathbf{r}_1 \cdots \mathbf{r}_n$ respectively the total momentum is

$$\sum_{i=1}^n m_i \cdot \frac{d\mathbf{r}_i}{dt}.$$

From the fundamental principles of mechanics, the time rate of change of the total momentum of a system of particles is equal to the vector sum of all the external applied forces. For a system subject only to the initial interaction forces between the particles, the total momentum remains constant.

MOMENTUM THEOREM OF FLUID MECHANICS. The propulsive force on a body immersed in a stream of fluid is the difference between the increase in momentum of the fluid, and the increase in the pressure integrated over the effective surfaces of the body.

MONITOR. (1) An ionization chamber mounted in an x-ray beam and connected to a continuously reading instrument, to serve as an indicator of constancy of x-ray output. (2) An ionization chamber used to detect the presence of undesirable radiation in connection with health protection. (3) To check

by means of a receiver the operation of a telephone, radio, television or similar transmitter in order to ascertain the quality of transmission, fidelity to a frequency band, etc. The device used for (3), or the action of using the devices (1) and (2).

MONOCOQUE. A type of airframe construction without framing which relies for its rigidity primarily upon the surface or skin, which may be of sheet metal or of layers of veneer; a shell-like structure.

MONOCOQUE, SEMI. Semi-monocoque.

MONOGOLE. A monopropellant.

MONOPROPELLANT. A rocket propellant which consists of a single phase, especially a liquid, containing both fuel and oxidant, combined or mixed. It does not require an oxidizer. Some monopropellants decompose to furnish their own oxidant and reductant. Monopropellants give a simpler installation within the rocket, one propellant tank, one pump and one set of valves and feed lines. Their great disadvantage is that they are likely to undergo premature ignition because of natural instability. Some monopropellants are: **Nitromethane, diethylene glycol (DINA), diethylene glycol dinitrate (DEGN), nitroglycerin, methyl nitrate, hydrazine, ethyl nitrate, ethylene oxide, n-propyl nitrate.**

MONOPULSE RADAR. Radar, Monopulse.

MONROE EFFECT. Reinforcement of explosive waves by each other to produce a stronger resultant wave. The concept is used in the design of **shaped charges.**

MONTE-CARLO METHOD. A method of solution of a group of physical problems by means of a series of statistical experiments which are performed by applying mathematical operations to random numbers. This method applies most directly to stochastic problems.

MONTH. Originally the term month was used to indicate the period of time required for the **moon** to pass from some particular phase (i.e., full moon) back to the same phase again. Astronomically the term is used to indicate the period of revolution of the moon from any reference point back to that reference point again. The sidereal month is the time

it takes the moon to make one revolution from a given star back to the same star again as seen from the center of the earth. It averages $27^d.32166$ (mean solar days) but it varies approximately 7 hours on account of **perturbations.** From the purely mechanical point of view this is the true revolution period of the moon. The synodic month is the period described above (i.e., the period between successive full moons) and averages $29^d.53059$ varying by more than 13 hours principally because of eccentricities in the moon's **orbit.** Other types of month which are in use with their average lengths in days are: Tropical (from one celestial **longitude** back to the same again) $27^d.32156$, Nodical (from one **node** back to the same) $27^d.21222$, Anomalistic (from some point in orbit back to same) $27^d.55460$, and Solar ($\frac{1}{12}$ of a tropical year) $30^d.43685$.

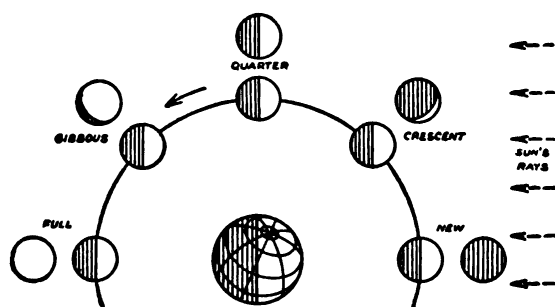
MOON. The moon, the **satellite** of the earth, is, next to the sun, the most conspicuous of all of the astronomical objects. In spite of its apparent brightness and the fact that it has been the subject of countless legends and superstitions throughout the existence of mankind, the moon is in reality a small and unimportant member of the vast universe of celestial objects.

The physical and orbital data regarding the moon will be found in the tables of satellites of the solar system (Page 540). All observational evidence and theoretical calculations point to the fact that the moon is devoid of any **atmosphere.** Its distance from the sun averages, over a period of time, the same as the distance of the earth from the sun, with the result that the moon will receive the same amount of heat as does the earth. Knowing the reflecting power of the moon we can calculate the surface temperature of the moon. It is found that at noon on the moon the temperature is approximately 400°K. (261°F.), while at midnight, the temperature falls to about 120°K. (-243°F.). These calculated values have been verified observationally. Such extremes of temperature coupled with the lack of atmosphere preclude the possibility of there being on the moon any form of life such as we know it on the earth.

Probably the most strikingly interesting characteristic of the moon, as seen by the average observer without a telescope, is the so-called **phase change.** The moon shines solely by reflected sunlight and the phase

changes can best be understood by reference to the accompanying figure on which the names of the various phases are given. It should be noted that at the time of new moon the dark side of the moon is toward the earth and the moon is invisible, in fact it is a safe statement to make that no one has even seen a strictly "new" moon, except possibly at the time of a solar eclipse. It should further be noted that the illuminated side of the moon is always toward the sun so that, against a dark sky, the horns of the crescent always point away from the horizon.

At the time when the moon is slightly beyond new phase, and appears as a thin crescent in the western sky, the earth, as seen from the moon, is practically in full phase. That part of the moon which is not illuminated by direct sunlight is lighted by "earthlight" and is vis-



The phases of the moon. The outer figures show the phases as seen from the earth.

ible as "the old moon in the new moon's arms." The apparent difference in size between the sunlit crescent and the earthlit moon is an optical illusion due to the fact that a brighter object always appears larger than a fainter one.

The moon rotates on its axis in the same direction that the earth rotates, and in the same direction that the moon revolves about the earth. This means that the moon keeps approximately the same face toward the earth at all times. Hence, at periods of full moon we always see the face of the "man in the moon" and never the back of his head. However, due to effects known as **librations**, the moon apparently rocks slightly in all directions. As a result of these librations, about 41% of the moon's surface is always visible from the earth, about 41% has never been observed from the earth, and the remaining 18% is invisible or visible, depending upon the particu-

lar time of observation and position of the observer on the surface of the earth.

The study of the surface geography of the moon, or selenography, has been carried on ever since the invention of the telescope and that portion of the surface which is visible to the earth has been very carefully mapped. From the reflecting power of the surface and the characteristics of the reflected light we find that the surface is composed of a brownish-yellow rock. Much of the lunar nomenclature was developed 2 or 3 centuries ago and the descriptive terms are unfortunate. For example, the so-called seas, which are the most conspicuous features in a small telescope, are in reality broad flat plains. In addition to these plains we find mountain ranges with peaks comparable in height to the highest peaks on the earth; rills, or cracks in the surface as much as $\frac{1}{2}$ mile wide and of undetermined depth; rays, or bright streaks radiating out from certain points on the surface; and the so-called lunar craters.

Certainly the most remarkable of all of the surface features are the so-called craters. In accordance with a system of lunar nomenclature first introduced in the middle of the 17th century by Riccioli these craters bear the names of distinguished scientists and philosophers. The craters have a generally circular form, with high mountain ranges rising abruptly from the surface of the moon and frequently with an isolated peak near the center. There are over 30,000 of these craters ranging in size from great walled plains with diameters of nearly 150 miles down to small craterlets 1000' or less in diameter. In some cases the floors of the craters are depressed below the surrounding surface of the moon, while in others the floors are elevated. The surface of the plain inside the walls is very rough in some cases and very smooth in others.

MOON MESSENGER. The name ascribed by the astronomical science writer Willy Ley for the unmanned rocket proposed to be fired to impact on the moon. It is to contain an explosive charge to distribute a colored dye marker on the moon surface.

MOON ROCKET. Lunar probe.

MOSAIC. In television, the photosensitive surface in an **iconoscope**, or **orthicon** camera-tube. In this tube the light rays are transformed into equivalent electrical charges.

MOTION, EQUATIONS OF. A set of equations, generally in differential form, which when solved yield information concerning the subsequent motion of a particle or system of particles whose initial conditions are known. The initial conditions are specified by the initial position and initial velocity. A knowledge of the resultant force acting on the system at any instant is also necessary. There are several equivalent forms in which the equations of motion may be expressed. (See **Newton laws of motion.**)

MOTION, PARAMETRIC EQUATIONS OF. In certain cases of motion in two and three dimensions, the solutions of the differential equations of motion yield the displacements of the components along the coordinate axes as a function of time, with the general form of these parametric equations:

$$x = f_1(t)$$

$$y = f_2(t)$$

$$z = f_3(t).$$

These are called parametric equations of the path with the time t as the parameter. To determine the path of the motion in the particular two or three dimensional space, it is necessary to eliminate the time and obtain a function of the form $\Phi(x, y, z) = 0$.

The motion of a projectile and the composition of simple harmonic motions in a plane are examples.

MOTOR. A device which produces motion by transforming into mechanical energy another form of energy, e.g., electrical or heat energy. The heat energy may be obtained from a chemical or nuclear reaction.

MOTOR CASE. Motor chamber.

MOTOR CHAMBER. In solid propellant rocket usage, the pressure container or bottle containing the propellant to which is attached the nozzle.

MOTOR, ELECTRIC. A machine which, receiving electrical energy, converts it into mechanical energy. Since there are so many different types of electric motors, it seems logical to begin a discussion of them with some attempt at classification of the principal types. Such a classification is given below, and includes the major types in present-day use.

- A. Direct-current types.
 - 1. Shunt.
 - 2. Series.
 - 3. Compound. } Straight or Interpole
- B. Alternating-current types.
 - 1. Synchronous.
 - 2. Induction.
 - a. Polyphase.
 - (1) Squirrel-cage rotor.
 - (2) Wound rotor.
 - (a) Slip ring.
 - (b) Brush shifting.
 - b. Single-phase.
 - (1) Split-phase.
 - (2) Repulsion-induction.
 - (3) Condenser.
 - c. Universal (series).

Electric motors are built in a range varying from outputs of $\frac{1}{100}$ of a **horsepower** up to well over 1000 hp. A 50-hp motor is considered a large one, and the majority of electric motors now in use ranges between $\frac{1}{4}$ and 10 hp. Standard motor sizes above the small fractional sizes are $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1 , $1\frac{1}{2}$, 2 , 3 , 5 , $7\frac{1}{2}$, 10 , 15 , 20 , 25 , 30 , 40 , and 50 -hp. Sixty-cycle synchronous speeds are 3600, 1800, 1200, 900, 720, 600, 514, and 450 rpm. Full-load induction motor speeds are 2-5% less than these. The efficiency of the electric motor ranges from 75-95%. It is higher in large motors than in small. Induction motors are more efficient the higher the rated speed, but d-c motor efficiency is little affected by speed. Efficiency is often secondary to reliability; nevertheless, it is a factor to be considered, particularly if the drive is heavy and the motor is well loaded over a considerable part of the time. **Direct-current** motors are much less frequently employed than **alternating-current**, because of the preponderance of a-c over d-c systems. However, speed control and starting torque are so excellent with d-c that it is frequently used in a-c territory where these characteristics are important.

MOTOR ROCKET. A generic term for a rocket consisting of the assembled propellant, case, ignition system, nozzle and appurtenances. (See **rocket engine.**)

MOTORBOATING. In radio, a characteristic audio frequency vibration caused by improper tuning of the set. It is a symptom of malfunctioning of superheterodyne receivers

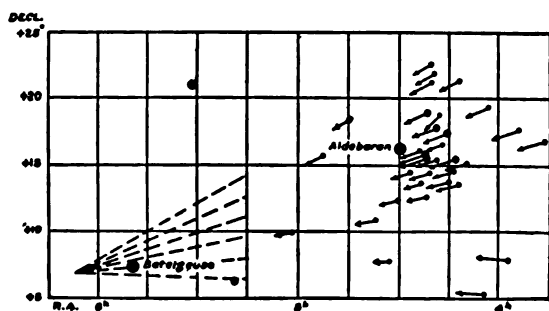
and is used as an indication in trouble-shooting.

"MOUNTAIN EFFECT." The effect of rough terrain on radio-wave propagation, which causes reflected waves to react with the direct waves in a manner which obscures the true direction of the source. This effect creates one form of error in radio direction-finding.

MOUSE. (1) The radar station used as a reference by an airplane using the Oboe system. (2) A particular satellite vehicle, named for "Minimum Orbital Unmanned Satellite of the Earth" as conceived by S. F. Singer.

MOVING CLUSTERS. Statistical studies of the various stellar motions, such as **proper motion**, **radial velocity**, and **space velocity**, have proved conclusively that there are a number of groups of stars that are moving through space together. These motions can be considered under two main headings: moving clusters and star streams.

A relatively small number of stars which are known to be moving through space together in parallel paths constitute what is known as a moving cluster. Due to a perspective effect, similar to that discussed in connection with meteoric **radiant points**, the proper motions of the members of the moving cluster will appear to be converging upon, or diverging from, a point on the celestial sphere. The apparent convergence of proper motions of a moving cluster is illustrated by the figure which shows a group of stars in the con-



Convergence of stars in Hyades cluster in Taurus.
(Adapted from a diagram by Lewis Boss.)

stellation of Taurus which form part of the so-called Hyades moving cluster. About 150 stars have been found which belong to this cluster. A number of moving clusters have

been found in various parts of the sky and they frequently carry the name of a constellation in which a number of the members of the cluster are found, e.g., the Ursa Major group, the Scorpio-Centaurus group, the Orion group, etc. It must not be understood that all members of a particular moving cluster are to be found in the constellation for which the group is named, for such is rarely the case. For example, members of the Ursa Major cluster are to be found not only in the constellation of **Ursa Major**, but also in **Canis Major**, **Corona Borealis**, **Auriga**, and others. Also there are two clusters in the constellation Taurus, the Pleiades and the Hyades.

MOVING-COIL GALVANOMETER. Galvanometer, moving-coil.

MOVING TARGET INDICATOR (MTI). A radar presentation which shows only targets which are in motion, thus improving their contrast to ground clutter. Signals from stationary targets are subtracted out of the return signal by the operation of a suitable memory circuit. (See **Doppler Radar**.) (See Figure on Page 405.)

MS. Margin of Safety.

MSA. Mutual Security Agency.

MSP. Mutual Security Program.

MTBF. Mean-Time Between Failure.

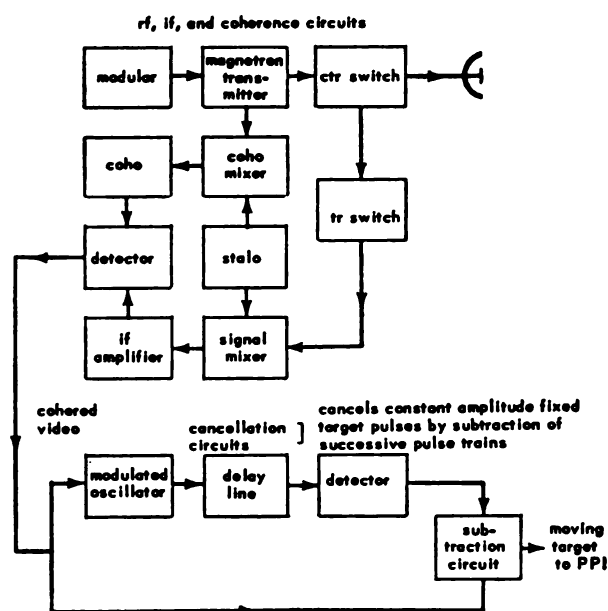
MTI. Moving Target Indicator.

m-TYPE SEMICONDUCTOR. An extrinsic semiconductor in which the conduction-electron density exceeds the hole density.

MU FACTOR. In an electron tube the ratio of the change in one electrode voltage to the change in another electrode voltage while a specified current remains unchanged and all other electrode voltages are maintained constant. The term therefore expresses the amplification power of the tube. A high-mu tube would be capable of high amplification. (See **Amplification Factor**.)

MUF. Maximum Usable Frequency.

MULTIMETER. A measuring instrument capable of measuring more than one electrical quality, including potential, current and resistance. Multimeters can be designed to cover any combination desired.



Moving target indicator (MTI) Radar.

MULTIPATH RECEPTION. A source of distortion or confusion in a signal received by a radio or radar receiver resulting from the fact that direct and reflected signals have different transmission times. When the two signals arrive at the receiver at slightly different times, they are out of phase and interfere. Multipath distortions are reduced by vertical polarization, since horizontally-polarized waves are more likely to be reflected from horizontal surfaces such as the ionosphere, the surface of the earth, or the wings of aircraft. Multipath distortions are particularly undesirable in equipment which is measuring phase shift of incoming signals (e.g., DOVAP equipment). Multipath reflections affect radar receivers when a **beacon** is used (as in tracking a missile), in cases where the receiver also obtains a skin return from a reflective surface. Diagonal bracing wires on towers and poles are a serious problem, since they often rotate the plane of polarization of signals.

MULTIPLE GRAIN. An assembly of solid propellant tubular grains inside a rocket motor case; only exterior surfaces of the individual grains are burning surfaces. Total burning surface decreases as the combustion proceeds; the thrust versus duration curve is regressive.

MULTIPLE HOP. A radio transmission path, characterized by more than one reflection from the ionosphere and the earth. Mul-

tipath transmission can result from different depths of ionospheric penetration as well as from varying frequency of transmissions.

MULTIPLE-PERFORATED SINGLE CYLINDRICAL GRAIN. A solid propellant grain with several perforations parallel to its longitudinal axis, all of the burning surfaces being approximately the same distance apart.

MULTIPLE REFLECTIONS. When a ray of light strikes a transparent plane-parallel plate, some of the radiation will be reflected, while some will enter the plate and be partly reflected back and forth between the two sides of the plate. At each reflection, some of the radiation will escape to the outside (provided the angle of the ray inside the plate with the normal to the surface is less than the critical angle). The radiation which is reflected on the first contact with the plate is of opposite phase with that which has entered and then been emitted from the entrant side. It can be shown that the total energy of the first reflected beam is equal to the total of the other reflected light on the entrant side so that total interference occurs when $2nd \cos \phi = m\lambda$, n being the refractive index of the plate, d its thickness, ϕ the angle of incidence and $m\lambda$ an integral number of wavelengths. There is never total interference for the transmitted beam.

MULTIPLE SHOCK INTAKE. In air-breathing engines, a means of increasing the total pressure recovery of a **diffuser** by reducing the losses encountered with a single normal shock.

MULTIPLEXER. A device by which simultaneous transmission of two or more signals may be made using a common carrier wave.

MULTIPLEXING ("TIME SHARING" OR COMMUTATION). Denotes the simultaneous transmission of several functions over one link without loss of detail of each function, such as amplitude, frequency, phase, or wave shape. Very high-speed commutation that would satisfy these conditions could, in special instances, be correctly classified as multiplexing. However, to prevent confusion, the term "commutation" is still preferred whenever a switch is used.

MULTIPLIER-PHOTOTUBE. Electron-multiplier phototube.

MULTIPROPELLANT. A rocket propellant consisting of two or more substances fed separately to the combustion chamber. (See **bipropellant**.)

MULTISTAGE ROCKET. Rocket, multi-stage.

MULTIVIBRATOR. A relaxation oscillator employing two electron tubes to obtain the in-phase **feedback voltage** by coupling the output of each to the input of the other through, typically, resistance-capacitance elements. (See Fig. 1 and 2.) The fundamental frequency is determined by the time constants of the coupling elements, and may be further controlled by an external voltage. When such circuits are normally in a nonoscillating state and a trigger signal is required to start

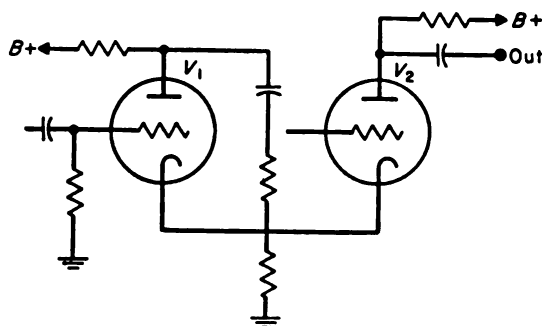


Fig. 1. One-shot multivibrator.

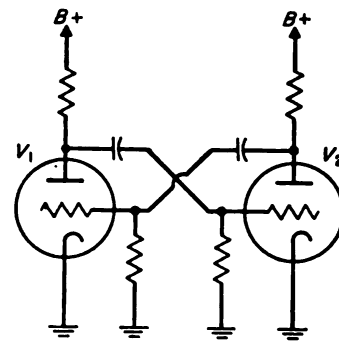


Fig. 2. Free-running multivibrator circuit.

a single cycle of operation, the circuit is commonly called a one-shot, a flip-flop, or a start-stop multivibrator.

MULTIVIBRATOR, ASTABLE. A **multivibrator** which can exist in either of two quasi-stable states, and switch rapidly from one state to the other.

MULTIVIBRATOR, BISTABLE. A circuit with two stable states which requires two trigger pulses to complete one cycle. It is commonly referred to as a trigger circuit, Eccles-Jordan trigger circuit, or scale-of-two circuit.

MULTIVIBRATOR, MONOSTABLE. A **multivibrator** with one stable and one quasi-stable state. A trigger is required to drive the unit into the quasi-stable state, where it remains for a predetermined time before returning to the stable state. Sometimes referred to as the one-shot.

MUSH COIL. In electrical usage, a coil not wound in regular layers.

MUTUAL CONDUCTANCE. Transconductance.

MUTUAL INDUCTANCE. The ratio of magnetic flux linking a circuit to the current in another circuit producing said flux.

MV. Millivolt.

MWO. Modification Work Order.

MX 904. An air-to-air missile developed by Hughes Aircraft Company. It was reported to fly at Mach 2.5 with a total weight of 75 pounds, 10 pounds of which were in the warhead.

MX 774. A U.S. surface-to-surface missile developed by Convair. Its length was 32 feet, with a maximum diameter of 30 inches. The configuration consisted of four tail fins in a cross formation. This missile was scheduled

to reach an altitude of 100 miles, using a bi-propellant rocket engine. Guidance was of the autopilot type. This research later developed into the **Atlas Project**.

N

N. (1) Avogadro number (N). (2) Nitrogen (N). (3) Neutron (n). (4) Normal (solution) (N or n). (5) Number (n). (6) Number of molecules, atoms or nuclei (N), if kinds are plural ($N_{1,2}\dots$). (7) Number of radioactive atoms at time t (N). (8) Number of radioactive atoms, initial (N_0). (9) Number of radioactive atoms, initial, if kinds are plural ($N^0_{1,2}\dots$). (10) Number of components (phase rule) (n). (11) Total number of lines in a grating (N). (12) Number of molecules per unit volume (n). (13) Number of molecules per cm^3 under standard conditions (Loschmidt number) (N_0). (14) Number of moles (N). (15) Number of revolutions per unit time (n). (16) Number of turns of conductor (N). (17) Nusselt's number (N). (18) Yawing moment (N). (19) Direction cosines (l, m, n). (20) Refractive index (n), group refractive index (n_g). (21) Shear modulus of elasticity (n).

Na. Sodium.

NAA. National Aeronautical Association—North American Aviation Incorporated; Inglewood, California.

NACA. National Advisory Committee for Aeronautics, now the **NASA**.

NACELLE. In aerodynamics, the streamlined housing around otherwise blunt or angular objects, e.g., the cover and streamlining around a motor. It includes the entire tear-drop shaped container. The term usually refers to engine nacelles, but may also be used to describe any tear-drop shaped, hollow surface on a missile or aircraft. It can be an enclosed shelter for personnel or some device.

NaDevCen. Naval Air Development Center.

NADIR. (1) A point on the celestial sphere 180 degrees from the zenith, i.e., directly beneath the observer. (2) The photographic nadir is that point at which a vertical line through the perspective center of the camera lens pierces the plane of the photograph. It

is also referred to as the nadir point or ground point, and is actually the point on the ground vertically beneath the perspective center of an aerial camera lens.

NAKA. A U.S. air-to-air 1.5-inch unguided rocket.

NAMTC. Naval Air Missile Test Center; Point Mugu, California.

NAPALM. A chemical compound used to gel gasoline for use in incendiary bombs.

NAPIER. A British ramjet test missile approximately 18-20 feet long.

NAS. National Academy of Sciences.

NASA. National Aeronautics and Space Administration.

NASTY. A small unguided U.S. air-to-air rocket missile.

NATIV. A North American Aviation instrumentation test vehicle. It was similar in appearance to the German Wasserfall missile, but did not have its forward fins, it was much smaller (14 feet long and 18 inches in diameter). It was fired from a 125-foot tower (similar to the **Aerobee**) reaching an altitude of 10 miles. It weighed 1,237 pounds at take-off.

NATTER. Ba 349.

NATURAL FREQUENCY. Frequency, natural.

NATURAL PERIOD. Period, natural.

NAUTICAL ALMANAC. In full, **American Nautical Almanac**. An annual publication prepared by the U.S. Naval Observatory, giving the positions of the various celestial bodies used by navigators, times of sunrise, sunset, moonrise, moonset, and other information of interest to navigators at sea. (Cf. **Air Almanac**.)

NAUTICAL MILE. Originally the nautical mile was defined as the length of 1 minute of arc on a great circle drawn on the surface of a sphere with the same area as the earth. In accordance with this rigorous definition the length of the nautical mile is 6080.27', and this is the value of the U.S. Hydrographic Office nautical mile. The international nautical mile is 6076.1033 feet (1852 meters). The U.S. Air Force nautical mile is 6076.10333 feet. The value calculated for the Clarke Spheroid of 1866 is 1,853.248 meters or 6,080.20 feet.

NAVAHO. A U.S. Air Force intercontinental missile of an aerodynamic type, developed by North American Aviation Co. The project began in 1946 and was terminated before completion of the first prototype in 1957. It was to be an inertially-guided aerodynamic type missile of supersonic velocity (Mach 3), capable of 5,000 miles range. It was to be powered by two Curtiss-Wright 48 inch ramjet engines, with liquid-propellant rocket boost to ramjet speed. The U.S.A.F. Dictionary of 1956 described the Navaho as follows: "The missile is rocket-boostered (by several large North American Rocketdyne liquid propellant rockets) to approximately 50,000 feet and then continues to 100,000 feet on its own engines." It was designated the SM-64. Its first design model had a canard configuration with horizontal stabilizers forward. The initial testing of the Navaho configuration began with the X-10, a recoverable scale model of the prototype, powered by two conventional turbojet engines. The first actual Navaho missiles fired were failures. The first four launchings were conducted without successful boost to flight speed. The fifth flight was a success. It was announced in 1957 that there were four more Navaho interim prototype vehicles remaining to be fired. The program was then cancelled, but in 1958, the U.S. Air Force decided to revive the Navaho program in the Rise program; and the first firings took place in the Summer of 1958. (See **missile, guided**.) (See also illustration on Page 282.)

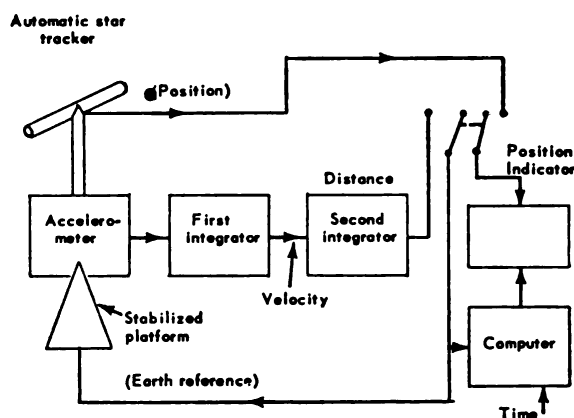
NAVAR. A system proposed for air navigation and control, based principally upon the use of radar equipment both in the aircraft and on the ground. It is a long range system suitable for jet-type aircraft.

NAVIGATION. (1) Originally defined as the science of conducting a ship from place to

place on the surface of the earth, the meaning of navigation is today generally extended to determining (one's) position on or off the surface of the earth, and projecting a course to follow to a destination. It consists of four basic operations: dead-reckoning, fixing, pilotage, and homing (use of beacons). (2) In missile guidance, there are three methods of line-of-sight navigation. See **navigation, pursuit; navigation, fixed lead; and navigation, proportional**. (See also **astronavigation; ACN; navigation, hyperbolic; and ATRAN**.)

NAVIGATION, AUTOMATIC CELESTIAL. Star tracking; navigation, celestial.

NAVIGATION, CELESTIAL. Navigation by means of observations of celestial bodies. A system wherein a missile, suitably instrumented and containing all necessary guidance equipment, may follow a predetermined course in space with reference primarily to the relative positions of the missile and certain pre-selected celestial bodies. Determination of the local vertical to the earth's surface is requisite. (See figure.)



Functional schematic celestial navigation system.

NAVIGATION, CONSTANT-BEARING. That missile trajectory wherein it maneuvers so that the seeker is looking at the target in a direction that is fixed in space.

NAVIGATION, DECCA. Navigation, hyperbolic.

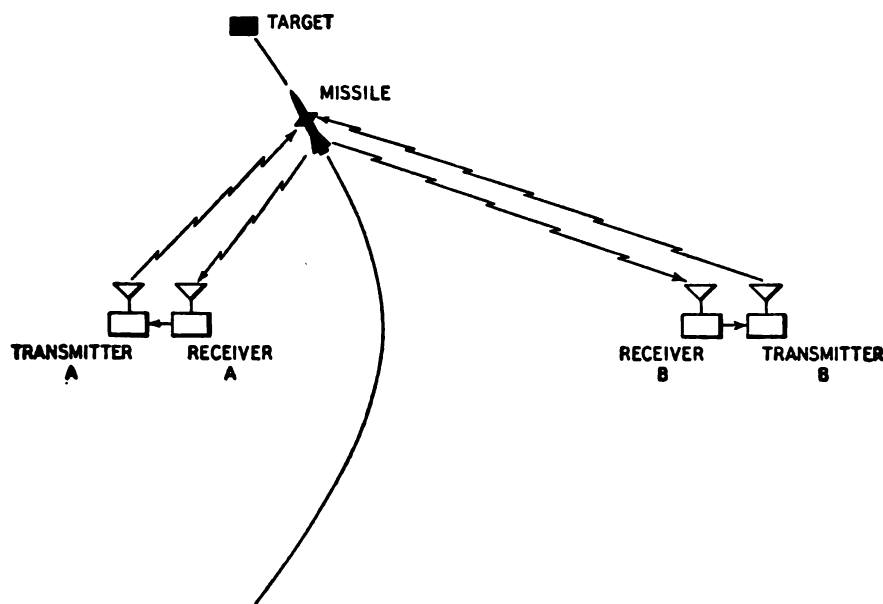
NAVIGATION, FIXED LEAD. A navigation path used in guided missile guidance schemes where the missile is pointed ahead of the moving target by a certain fixed angle.

NAVIGATION, HYPERBOLIC. A general method for determining lines of position by

measuring the difference in distance of the navigator or navigation apparatus from two or more stations of known position. The difference in distance is determined by measuring the difference in time of arrival of signals transmitted from two or more stations. Although a great variety of signaling methods is theoretically possible, only radio waves are now commonly used in hyperbolic navigation. One system, using **continuous wave** signals, is known as **DECCA**. **LORAN** and **GEE** are systems using signals transmitted as pulses. One transmitting station is the master station, with the other stations or station, sepa-

DECCA, and **LORAN**; the fundamental characteristics are all the same. In the **DECCA** and **GEE** system, the master station operates in conjunction with two or more slave stations. In the **LORAN** system, the master station operates with one slave station. **SHORAN** is a short-range system.

NAVIGATION, PROPORTIONAL. A homing guidance technique in which the missile turn rate is directly proportional to the turn rate in space of the line-of-sight; the seeker tracks the target semi-independently from the missile maneuvers.



Application of hyperbolic navigation to missile guidance.

rated from 75 miles to 1200 miles, being slave stations. The cycle of transmission always begins at the master station, which transmits the signal in all directions. The arrival of the master signal at the slave station "triggers off" the slave which, in turn, transmits a signal. Points of constant difference in time of arrival of the two or more signals will fall on hyperbolas, with the transmitters at the foci. The accuracy of the line of position which can be established by the navigator or the navigating apparatus varies from 200 yards to 2 miles depending upon propagation conditions, the distance and orientation of the observer or the receiver from the base line between stations and upon the type of system and equipment used. Although the navigator's equipment differs in details for **GEE**,

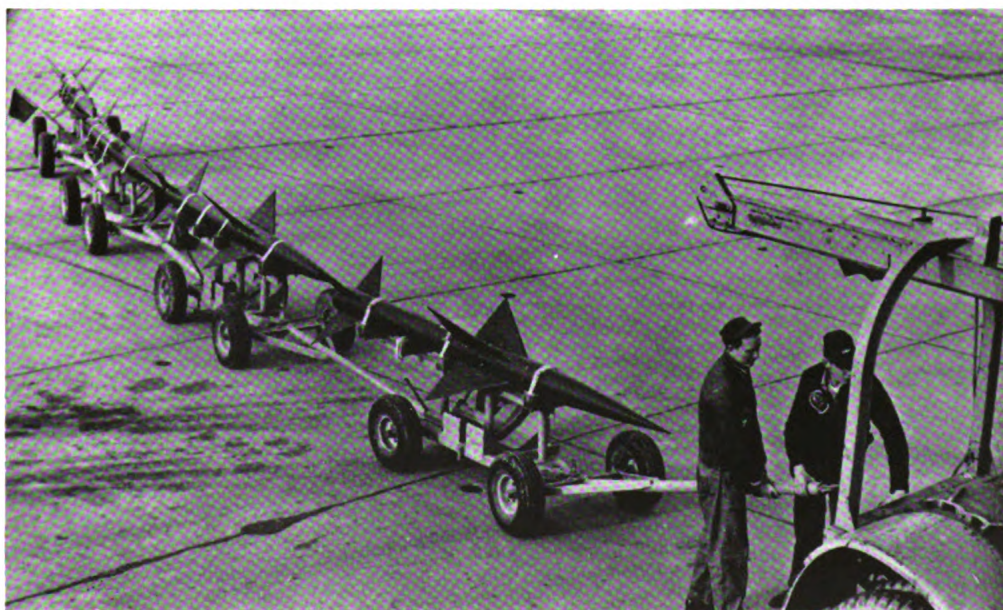
NAVIGATION, PURSUIT. The form of **guidance** (i.e., navigation) which makes use of the pursuit curve. It is a no-lead type of flight which keeps the missile always pointed toward the target. It is a feasible type of guidance only for homing type missiles which approach their targets from ahead or the rear.

NAVIGATION SYSTEM, INERTIAL. A system which is functionally the same as inertial guidance except as to end use. It is essentially a form of dead-reckoning device. (See **guidance, inertial**.) This means that the geographic position (latitude and longitude or equivalent) of both the starting point and destination must be known and must be set into the equipment.

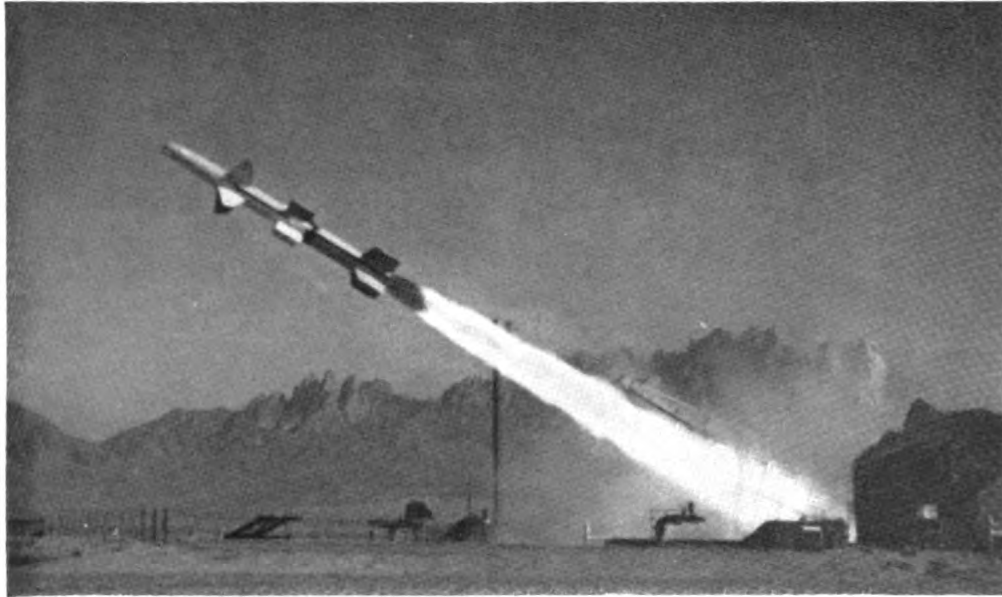
An inertial navigation system usually re-



The Air Force's Northrop SM-62 SNARK long-range strategic missile when undergoing tests at the Air Force Missile Test Center, Patrick Air Force Base, Florida. (*U.S. Air Force Photograph*)



Missilemen move out SPARROWS (air-to-air missiles) to be loaded in the wing launchers of Navy cutlasses (F7U) at Naval Air Station, Ocean, Virginia. (*U.S. Navy Photograph*)



TALOS Missile. (*U.S. Navy Photograph*)



Test and evaluation of TERRIER guided missiles by USS Mississippi (EAG 128) at sea. TERRIER launched from the USS Mississippi. USS Krause (DD 849) in background. (*U.S. Navy Photograph*)

quires two or three accelerometers to sense aircraft/missile motion in the north-south direction, east-west direction, and in some applications, in the vertical direction.

NAVIGATIONAL INSTRUMENT. An instrument or device used in air navigation, as a directional gyroscope, magnetic compass, radio compass, gyro flux-gate compass, air position indicator, absolute altimeter, drift-meter, radio or radar.

NAVIGATIONAL PLANET. A term sometimes applied to Venus, Mars, Jupiter, or Saturn, the four planets commonly used in celestial navigation for obtaining lines of position.

NAVIGATORS' STARS. A list of 55 stars has been designated as the "navigators' stars." The list was selected to cover the entire celestial sphere in such a manner that a navigator, no matter at what season or in what part of the earth he may be operating, will have two or three navigators' stars available for observation. The names and positions of these stars are listed in the Air Almanac, published by the U.S. Naval Observatory, and in a number of other publications.

Nb. Niobium (Columbium).

Nd. Neodymium.

ND. Navy Department.

NDRC. National Defense Research Committee.

NDRC COMPOSITE PROPELLANTS. A family of molded composite propellants containing ammonium picrate and sodium or potassium nitrate, with a small quantity of a plastic binder (10%). The propellant is hard and rigid. It has a specific impulse of approximately 170-175 lb-sec/lb. Changes in ambient temperature have only slight effects upon performance. The exhaust from these propellants contains solid particles and is smoky. The family members range widely in performance by the use of varying proportions of ingredients. Normally ammonium picrate and sodium nitrate in approximately equal proportions (e.g., 45%-45%) are combined with a binder (e.g., butyl urea-formaldehyde resin).

Ne. Neon.

NEAR MISS. The strike of an explosive missile, especially of an aerial bomb, near but not on the object of attack, and usually close enough to it to cause effective damage.

NEARSONIC. Close to the speed of sound; that can be operated close to the speed of sound, as in nearsonic tunnel.

NEBULA. The term nebula (stellar nebula) was originally used by astronomers to describe any luminous spot which remained fixed relative to the stars. Before the application of the telescope to astronomy probably the only objects to which the term applied were those which we now refer to as star clusters, although there is a tenth-century reference to the great spiral in Andromeda. Following the application of the telescope to the study of the heavens, many more nebulous objects were discovered. Originally these objects were grouped into three main classifications: the diffuse nebulae, the planetary nebulae, and the spiral nebulae. Further research indicated that the spiral nebulae were very different from the other two. The application of the large telescopes of the present century has proved that they are in reality groups of stars, the term nebula has been dropped, and they are now referred to simply as spirals.

The diffuse nebulae are divided into two main groups, the dark and the bright. For many years the study of photographs of the Milky Way have shown "black holes" and other configurations that gave distinct evidence that clouds of dark material were obscuring stars that were beyond. Detailed investigation of the spectra of the spectroscopic binaries has shown that, although the great majority of the absorption lines from these objects shows the periodic displacement due to the motions of the components, nevertheless there are a few lines which remain stationary. The only plausible explanation is that these "stationary lines" are due to absorption by gaseous material in what had hitherto been referred to as empty space. When the color characteristics of stars in any one of the spectral classes are carefully studied, it is found that the more distant ones show a distinct reddening. The reddening can be well explained by the assumption of interstellar dust, which produces a reddening effect in much the same way that our atmosphere produces that reddening of sunlight which is more

evident when we see that object through a thick layer (e.g., at sunset).

The study of this interstellar material forms one of the most interesting problems of modern astrophysical research, but the conclusions at the present time are not positive. Suffice it to state that interstellar material exists and that it contains gases, in atomic or molecular state, and also some form of dust-like material. The temperature of the interstellar region is of the order of magnitude of absolute zero and we are unable to state just what sort of "dust" might be formed under these conditions.

There is considerable evidence that the interstellar material is present in all parts of space. However, there is a definite tendency for the mixture of gas and dust to collect in clouds and condensations. When one of these dark clouds is between the earth and a region where the stars are apparently most numerous, e.g., in the plane of the **milky way**, we can observe the darkness of the cloud against the background of stars. Such obscuring clouds of interstellar material are known as dark nebulae.

When one of these clouds is in the vicinity of a bright star, the intense radiation from the star will illuminate the cloud and we observe what is known as a bright diffuse nebulae. Studies of the spectra of these objects show that the light is made up both of reflected starlight and also of radiation from the interstellar material. The character of the reflected light is similar to that from the nearby stars. The radiation from the nebulous material itself, however, is of quite a different character from starlight. This nebular spectrum is of the bright-line type and is produced by the absorption of radiation from the star by the gas atoms, and then reradiation of this energy in frequencies characteristic of the gas atoms and their states of **ionization**. This hypothesis receives almost positive confirmation from the fact that the character of the nebular spectrum depends upon the spectral type of the nearby stars. If the star is hot (B-type) the nebular spectrum is rich with bright lines, but in the vicinity of a relatively cool star (M-type) the nebular spectrum is almost entirely that of reflected star light.

In addition to the diffuse nebulae, there are others that are known as planetaries, because of the fact that they have quite definite shapes

and look more or less like a planet when observed with a telescope. The general appearance of these objects, on detailed photographs, is that of a shell of gaseous material. They are generally elliptical in form, and may have the appearance of being made up of several elliptical shells with their axes at various angles to each other. Frequently a very blue, and hence probably very hot, star is observed at the center of the shell. Even when the star itself is not seen, astronomers are of the opinion that it is actually there, but that the shell is thick enough in the line of sight to prevent its being seen from the earth.

The spectra of the planetaries is, in general, the same as that of the diffuse nebulae found in the vicinity of B-type stars. In some cases, where the central star can be studied, variations in its light have been found and the nebula radiation is found to vary with that of the star. It is evident that the planetary nebulae are actually stars with very extended and attenuated atmospheres. There is no hypothesis to completely explain why some stars are in this condition, whereas the vast majority are not. Careful studies of the spectral lines from the planetaries indicate that the shell may be expanding. Expanding shells of gas have been observed around some **novae**, but the rate of expansion is far in excess of that found in the planetaries.

NEGATIVE FEEDBACK. In electromechanical devices, a process in which a part of the output signal of an amplifying device is returned to its input circuit in such a manner that it tends to cancel (is out of phase with) the input. It is also called **degenerative feedback** and is the opposite of **regenerative feedback**. (See **feedback** and **servomechanism**.)

NEMA. National Electronic Manufacturing Association.

NEON. Inert gaseous element. Symbol Ne. Atomic number 10.

NEPHOSCOPE. An instrument for determining the direction of cloud movement and, when used in conjunction with a timepiece, for determining the speed of such movement.

NEPTUNE. (For data, see **planet**.) Neptune itself is a **planet** somewhat less than 4 times the diameter of the earth, and a mass

slightly greater than 17 times that of the earth. Its mean density is only 0.35 times that of the earth, and this low value, coupled with the high value of the **albedo** (0.52), indicates that the planet probably has a thick layer of atmosphere.

Neptune is invisible to the naked eye, having a **stellar magnitude** of about 7.7, but can be readily observed in any telescope with aperture greater than 1". In small instruments it can only be distinguished from the stars by observing the change in position from night to night, but with larger instruments it appears as a small greenish disk. Observations indicate that the disk is apparently circular and that there are no distinguishable surface markings. Hence, telescopic observations tell nothing regarding the rotation period. In 1928 Moore and Menzel, at the Lick Observatory, found from spectroscopic observations, employing the **Doppler** principle, that the planet has a rotation period of slightly less than 16 hours, and that the planet is rotating in the same directional sense as most of the other members of the solar system.

Neptune has two **satellites**, one discovered by Lassell very shortly after the discovery of the planet. Telescopically the object is very faint and can only be observed with large instruments. From the brightness it is estimated that this satellite is similar to our own **moon** in size. The orbit of this satellite is inclined at about 20° to the plane of the planet's equator and the satellite revolves about the planet in the direction opposite to that of the majority of the members of the solar system. The smaller satellite was discovered by Kuiper in 1949.

NEPTUNIUM. Transuranium radioactive element. Symbol Np. Atomic number 93.

NET POSITIVE SUCTION HEAD (NPSH).

A parameter used in liquid rocket-engine turbopump design to describe the effective inlet pressure conditions to the propellant pumps. The pressure head available at the pump suction flange is provided by tank pressure head, elevation and acceleration forces (and is reduced by line friction and vapor pressure). NPSH is the head available to prevent pump cavitation.

NETWORK (ELECTRIC). A combination of elements, either as a combination of interconnected devices (such as **inductors**, **capaci-**

tors, **resistors**, **generators**, etc.), or as the abstraction of interconnected branches having the properties of **inductance**, **resistance**, **capacitance**, etc. (See **alternating-current circuit**; **Kirchhoff laws**.)

There are many different types of networks, named from the geometrical configuration of the circuit elements forming them. Where three or more admittances meet in a single point, it is called a "junction." An admittance connecting any two junction points is called an "arm" or "branch." A "mesh" within a network is a closed path through three or more junction points. A "C network" is composed of three branches in series, the free ends being connected to one pair of terminals and the junction points being connected to another pair of terminals. An "L network" is composed of two branches in series, the free ends being connected to one pair of terminals, and the junction point and one free end being connected to another pair of terminals. A "T network" is composed of three branches connected in a star with the three ends connected to an input, output and common terminal. An "H network" is composed of five branches, two in series between an input terminal and an output terminal, two connected in series between another input terminal and another output terminal, and the fifth connected from the junction point of the first two branches to the junction point of the second two branches. A "*pi* network" is composed of three branches connected in the shape of the letter π . A "O" network is composed of four branches connected in series.

NETWORK, DIFFERENTIATING. A **network** whose output is the time derivative of its input wave form. Such a network preceding a frequency **modulator** makes the combination a phase modulator; or, following a phase detector, it makes the combination a frequency **detector**. Its ratio of output amplitude to input amplitude is proportional to frequency, and its output phase leads its input phase by 90° .

NETWORK, INTEGRATING. A **network** whose output wave form is the time integral of its input wave form. Such a network preceding a phase modulator makes the combination a frequency modulator; or, following a frequency detector, makes the combination

a phase detector. Its ratio of output amplitude to input amplitude is inversely proportional to frequency, and its output phase lags its input phase by 90° .

NETWORK, LINEAR. A network for which the pertinent measures of all the waves concerned are linearly related. By "linearly related" is meant any relation of linear character, whether linear algebraic equation or linear differential equation or other linear connection. The term "waves concerned" connotes actuating waves and related output waves, the relation which is of primary interest in the problem at hand.

NEUTRAL BURNING. A burning process in a solid-propellant rocket which yields a constant pressure-time curve.

NEUTRAL STABILITY. The stability of a body such that no unbalanced forces act on the body if it is disturbed, i.e., its motions or oscillations neither increase nor decrease in magnitude.

NEUTRON. A neutral elementary particle of mass number 1. It is believed to be a constituent particle of all nuclei of mass greater than 1. It is unstable with respect to beta-decay, with a half-life of about 12 min. It produces no detectable primary ionization in its passage through matter, but interacts with matter predominately by collisions and, to a lesser extent, magnetically. Some properties of the neutron are: rest mass, 1.00894 atomic mass unit; charge, 0; spin quantum number, $\frac{1}{2}$; magnetic moment, -1.9125 nuclear Bohr magnetons; statistics, Fermi-Dirac.

Neutrons may be produced by various nuclear reactions, including such types as (α, n) , (γ, n) , (p, n) , or (d, n) , or they may be produced in nuclear reactors as a result of fission. In each of these processes fast neutrons are produced; in order to get slow neutrons, a moderator such as paraffin must be used to slow the neutrons down.

Neutrons are designated according to their energies, including the following:

Thermal neutrons, or neutrons in thermal equilibrium with the substance in which they exist; most commonly, neutrons of kinetic energy about 0.025 ev, which is about $\frac{1}{40}$ of the mean kinetic energy of a molecule at 15°C .

Epithermal neutrons, or neutrons having

energies just above those of thermal neutrons; the epithermal neutrons' energy range is between a few hundredths ev and about 100 ev.

Slow neutrons (a less definite classification), which may mean either neutrons having energies up to about 100 ev, or thermal neutrons.

Intermediate neutrons, which are neutrons having energies in a range that extends roughly from 100 to 100,000 ev. This range is above that of epithermal neutrons and below that of fast neutrons.

Fast neutrons, which are neutrons with energies exceeding 10^5 ev, although sometimes a lower limit is given.

Resonance neutrons may be either, (1) for a specified nuclide or element, neutrons that have energies in the region where the cross section of the nuclide or element is particularly large because of the occurrence of a resonance. For example, cadmium resonance neutrons have energies between 0.05 and about 0.3 ev. (2) Neutrons having kinetic energies in the region of values for which prominent resonances are encountered in many nuclides; loosely, epithermal neutrons.

Prompt neutrons are those neutrons released coincident with a fission process.

Delayed neutrons are those neutrons released subsequently in a fission process, or, more generally, neutrons emitted by excited nuclei formed in any radioactive process (beta-disintegration, in all cases so far known). The neutron emission itself is prompt, so that the observed half-life is that of the preceding beta-emitter. The situation is similar to that involving gamma-ray emission, which is a competing process. Delayed neutron emission is possible only if the excitation energy of the product nucleus exceeds the neutron binding energy for that nucleus. The chemistry of the delayed neutron emitter is that of the beta-activity; thus Br^{87} , I^{137} and N^{17} are delayed neutron precursors, although the neutron emission actually takes place from excited nuclei of the products Kr^{87} , Xe^{137} and O^{17} .

NEUTRON CROSS SECTION. A measure of the ability of a material to interact with neutrons by scattering, capturing, or being fissioned by them.

NEUTRON FLUX. A term used to express the intensity of neutron radiation, usually

used in connection with the operation of a nuclear reactor.

NEUTRON NUMBER. The number of neutrons in a nucleus. (See **atomic structure**.) Its symbol is N , and it is indicated symbolically when desired by a subscript number *following* the symbol of the nuclide. The neutron number for a given nuclide is equal to the difference between the mass number for that nuclide and the atomic number.

NEUTRON SOURCE. Any material that emits **neutrons**, e.g., a mixture of radium and beryllium. A neutron source may be introduced into a **nuclear reactor** as part of the start-up procedure. The use of a neutron source is a safety measure to insure having at the outset a neutron flux large enough to be distinguished from background and measured quickly. Otherwise, as control rods are withdrawn, the reactor might reach a critical condition before its flux has risen high enough for the control system to operate. Especially if the reactor had become prompt-critical, a rapid and uncontrolled increase in power to a harmful level then might result. When such a source is used, the control instruments show at an earlier stage the approach to critical conditions as safety and control rods are withdrawn.

NEUTROPAUSE. **Neutrosphere.**

NEUTROSPHERE. The region of the atmosphere, extending from the earth's surface to approximately 75 kilometers, which is electrically neutral. Above this altitude the **ionosphere** begins. The dividing line between the neutrosphere and the ionosphere is called the neutropause.

NEWTON. A unit of force in the MKS system of measurement. It is that force producing an acceleration of one meter per second per second in a mass of one kilogram. It is equal to 10^5 dynes or about 0.225 pounds.

NEWTONIAN TELESCOPE. A reflecting telescope employing a parabolic objective mirror, an optically flat mirror to reflect the image outside the tube and a secondary lens or eyepiece for focusing it.

NEWTON'S LAW OF MOTION. (1) Every body continues in its state of rest or of uniform motion in a straight line except in so far

as it may be compelled to change that state by the action of some outside force. (2) Change of motion is proportional to force applied and takes place in the direction of the line of the force. (3) To every action there is always an equal and opposite reaction.

Ni. Nickel.

NICKEL. Metallic element. Symbol Ni. Atomic number 28.

NIKE. A surface-to-air guided missile developed for the U.S. Army by Bell Laboratories Division of American Telephone and Telegraph Company in association with Douglas Aircraft (and others). The airframe was made by Douglas, and the electronic equipment by Western Electric Company. The Nike was the first post-war surface-to-air missile to be adopted for service use. The first operation sites for the NIKE were at Fort Meade, Maryland, in connection with the defense of the City of Washington, D.C. Plans at that time called for all major cities to be protected by Nike. The first Nike was test fired at White Sands Proving Ground in 1946.

The missile has a cruciform arrangement of triangular-shaped main supporting surfaces in line with cruciform control surfaces set on the airframe in a canard configuration. Launching is from an adjustable launcher, with firing from a near-vertical position using a **RATO** booster. The missile guidance and control package is relatively simple, but the ground equipment is both costly and complex. The missile uses a bi-propellant liquid rocket engine manufactured by Aerojet Engineering Corporation. The rocket motor is approximately $18\frac{1}{2}$ inches long and $6\frac{1}{2}$ inches in diameter, weighs about 20 pounds. It develops 2600 pounds thrust (at 10,000 feet) over a 35 second burning time. Fuel is **kerosene-FRNA**. (See illustration facing Page 282.) The missile flies in an "X"-orientation, which permits higher-g maneuvers and has a range of approximately 25 miles. Its official designation is SAM-A-7.

In 1956 the Nike was expanded into three separate projects: The Nike-Ajax, or conventional Nike I; The Nike-Hercules (or Nike-B), the atomic Nike with increased range and the Nike-Zeus, or anti-ICBM Nike. In 1956 there were approximately 100 tactical

Nike I sites around some 13 U.S. cities. (See **missiles, guided.**)

NIKE-AJAX. The U.S. Army surface-to-air, air defense missile in standard operational use. Its range: 10-30 miles, speed: 1,500 mph, weight: 1,000 pounds, length: 20 feet, diameter: 1 foot. Its command guidance system was developed by Western Electric, air-frame by Douglas Aircraft. Aerojet General and Bell Aircraft produced the liquid rocket. The missile was also denoted SAM-A-25, and before development of the Nike family of improved versions was known simply as Nike. The project was begun soon after World War II and resulted in operational missiles in 1953. (See **Nike**; and **missile, guided.**)

NIKE-B. An advanced version of the **Nike** about 27 feet in length, with a 14½ foot booster. It was later renamed the Nike-Hercules. (See **missile, guided.**)

NIKE-CAJUN. A two-stage solid propellant sounding rocket developed by the U.S. Army Ordnance's Ballistic Research Laboratories. It was designed to carry a 40-pound payload to an altitude of 100 nautical miles. The vehicle consisted of a **Nike** booster combined with a **Cajun** rocket second stage. The first such combination was fired by the NACA at Wallops Island, Virginia, in 1956 and attained a Mach 6 velocity. (See **missile, guided.**) (See illustration facing Page 283.)

NIKE-DEACON. A high altitude sounding rocket consisting of a **Nike** booster and a **Deacon** rocket. One of these reached 410,000 feet altitude in 1957. This combination was assembled as an inexpensive method for upper atmospheric measurements. (See **missile, guided.**)

NIKE-HERCULES. The U.S. Army surface-to-air, air defense missile put into operational status in 1957. It was formerly called Nike-B. It improved the **Nike-Ajax** system by extending its range, increasing the altitude capability and providing for a nuclear warhead. Its length was 39 feet (with booster) and diameter, 2 feet. The **Hercules** reportedly uses a single solid propellant Thiol sustainer motor and a cluster of Nike-Ajax type boosters. (See **missile, guided.**) (See also illustration facing Page 283.)

NIKE-ZEUS. The U.S. Army advanced **Nike** missile. In 1957 it was announced that the missile was being prepared for use as an antimissile missile (AMM). (See **missile, guided.**)

NIT. In information theory, the choice among equiprobable events. (1nit = 1.44 bits.)

NITRIC ACID. A common oxidizer for rocket fuels, having the chemical formula HNO_3 . It is used with petroleum derivatives and hydrazines, and in hypergolic combinations with aniline (and other organic amines) and vinyl or furan compounds. It is dangerous to handle, because it is corrosive to many substances, including human tissues, and because its fumes are toxic.

NITROCELLULOSE. A product of variable composition (depending upon the manufacturing process) obtained by nitration of cellulose. It is sometimes used as a **monopropellant**, or as a component of a double-base propellant for rocket motors, the other component sometimes being nitroglycerin.

NITROGEN. Gaseous element. Symbol N. Atomic number 7. Nitrogen is inert, and constitutes about 80% of the earth's atmosphere. Its variable solubility in the blood under pressure causes the disease known as bends, or **decompression sickness**.

NITROGEN TETROXIDE. A possible oxidizer for rocket fuels. It has the formula, N_2O_4 , boiling point, 70°F (21°C), freezing point, 12°F (-11.3°C), specific gravity, 1.49 at 20°C and density, 3.3 gm/liter at 21°C and 1 atmosphere.

NITROMETHANE. A possible rocket fuel. Its chemical formula is CH_3NO_2 ; boiling point, 214°F; freezing point, -19°F, and specific gravity, 1.14. As a monopropellant it has a **theoretical exhaust velocity** of 7008 feet per second, with a **specific impulse** of 218 lb-sec/lb at a chamber pressure of 300 psia and a chamber temperature of 3950°F. Chamber pressures for the burning of nitromethane are in the vicinity of 550 psia for catalyzed reactions, and between 800-1000 psia for non-catalytic burning. Nitromethane is sensitive to shock, but can be desensitized by adding 40% of methyl alcohol (lesser quantities are not adequate).

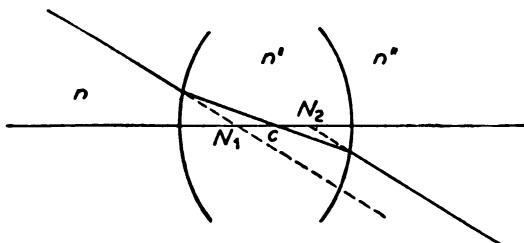
NME. National Military Establishment.

No. Nobelium.

NOCTILUCENT CLOUD. A rare luminous cloud formation noticed at night. It is believed to be a thin ice-crystal formation at extremely high altitudes (approximately 80 kilometers) which is visible only at night in the glancing rays of the sun. The clouds appear to have different colors, depending upon their altitudes above the horizon. They are reddish-brown near the horizon, white or blue-white at intermediate altitudes, and blue-gray near the zenith. They have occasionally been so luminous as to cause visible shadows on the ground.

NODAL LINES. On a vibrating diaphragm, lines along which no vibration takes place. If the diaphragm is circular they consist of two kinds, concentric nodal circles and nodal diameters.

NODAL POINT. (1) A point on a vibrating body having zero amplitude. The position of the nodal points vary, depending on the frequency of the vibration. (See **node**.) (2) Of all the rays that pass through a lens from an off-axis object point to its corresponding image point, there will always be one for which the direction of the ray in the image space is the same as that in the object space. The two points at which these segments, if projected, intersect the axis are called the nodal points, and the transverse planes through them are called the nodal planes. Only if n and n' , the indices of refraction in the object and image spaces, are identical are the nodal planes also the principal planes. C is the optical center of the lens.



NODE(S). (1) The points, lines, or surfaces in a standing wave system (see **wave**, **standing**) where some characteristic of the wave field has essentially zero amplitude. The appropriate modifier should be used with the

word "node" to signify the type that is intended (pressure node, velocity node, etc.). (See also **loop**.) (2) A terminal of any **branch** of a **network**, or a terminal common to two or more branches of a network. The terms junction point, branch point, and vertex may be used instead of node in this connotation. (3) A singular point on a curve having the property that two branches of the curve, with distinct tangents, pass through the point. Also called a **crunode**. (4) In astronomy, either of the two points where the orbit of a planet intersects the ecliptic, or where the orbit of a satellite intersects the plane of the orbit of its primary. The node passed as the body goes north is called the ascending node, and that passed going south, the descending node.

NOISE. (1) Any unwanted disturbance within a dynamic electrical or mechanical system, such as undesired electromagnetic radiation in any transmission channel or device. (2) Uncontrolled random disturbances which arise in a guided missile system as a result of various physical phenomena.

NOISE BANDWIDTH. In a dynamic electrical system or servomechanism, the frequency at which the open-loop gain equals unity defines the bandwidth effective in reducing system tracking error. It is frequently referred to as the noise bandwidth since below this frequency there is system **gain** and above there is **attenuation**. This frequency is used in determining phase margin. In some instances the asymptotic gain characteristic may, without great error, be used in this connection in place of the actual gain characteristic.

NOISE, ELECTRICAL. Unwanted electrical energy, other than cross talk, present in a transmission system or in a measuring device. For the sources and nature of such noise, see **noise**, **shot**; **noise**, **thermal**.

NOISE FACTOR (NOISE FIGURE). Of a linear system at a selected input frequency, the ratio of (1) the total noise power per unit bandwidth (at a corresponding output frequency) available at the output terminals, to (2) the portion thereof engendered at the input frequency by the input termination, whose noise temperature is standard (290°K) at all frequencies. For heterodyne systems

there will be, in principle, more than one output frequency corresponding to a single input frequency, and vice versa; for each pair of corresponding frequencies a noise factor is defined. The phrase, "available at the output terminals," may be replaced by "delivered by the system into an output termination," without changing the sense of the definition.

NOISE FACTOR (NOISE FIGURE), AVERAGE. Of a linear system, the ratio of (1) the total noise power delivered by the system into its output termination when the noise temperature of its input termination is standard (290°K) at all frequencies to (2) the portion thereof engendered by the input termination. For heterodyne systems, portion (2) includes only that noise from the input termination which appears in the output via the principal frequency transformation of the system, and does not include spurious contributions such as those from image-frequency transformations. A quantitative relation between average noise factor, F , and spot noise factor, $F(f)$, is

$$\bar{F} = \frac{\int_0^\infty F(f)G(f)df}{\int_0^\infty G(f)df},$$

where f is the input frequency and $G(f)$ is the ratio of (a) the signal power delivered by the system into its output termination to (b) the corresponding signal power available from the input termination at the input frequency. For heterodyne systems, (a) comprises only power appearing in the output via the principal frequency transformation of the system; in other works, power via image-frequency transformations is excluded.

NOISE FIGURE. Noise factor.

NOISE, MODULATION (NOISE BEHIND THE SIGNAL). The noise caused by the signal. The signal is not to be included as part of the noise. The term is used where the noise level is a function of the strength of the signal.

NOISE POWER, AVAILABLE. The maximum noise power that may be drawn from a network by a load whose impedance is the complex conjugate of the impedance of the network itself.

NOISE, RANDOM (OR FLUCTUATION). Noise characterized by a large number of overlapping transient disturbances occurring at random.

NOISE RATIO (NR). The ratio of the available noise power available at the output of a transducer divided by the noise power at the input.

NOISE, SHOT. Noise resulting from the random nature of the emission and flow of electrons in **electron tubes**.

NOISE SUPPRESSOR. A vacuum-tube circuit designed to suppress undesirable noise in a radio receiver. Suppressors are of two types, interchannel noise suppressors and large signal suppressors. The first acts as an **automatic volume control** to cut off the audio amplifier when no carrier is being received. The second is a peak limiting circuit to suppress all signals above a certain amplitude.

NOISE TEMPERATURE. At a pair of terminals and at a specific frequency, the temperature of a passive system having an available noise power per unit bandwidth equal to that of the actual terminals.

NOISE TEMPERATURE (STANDARD). The standard reference temperature T_0 for noise measurements is taken as 290 degrees K. $kT_0/e = 0.0250$ volt, where e is the electron charge and k is the **Boltzmann constant**.

NOISE, THERMAL (JOHNSON NOISE). The noise produced by thermal agitation of charges in a conductor. The available thermal noise power produced in a resistance is independent of the resistance value, and is proportional to the absolute temperature and the frequency bandwidth over which the noise is measured, as indicated by the formula:

$$N_t = 1.38 \times 10^{-23} T \Delta f$$

in which N_t is the available thermal noise power, T is the temperature of the resistance in degrees Kelvin, and Δf is the bandwidth in cycles per second.

NOL. Naval Ordnance Laboratory; White Oak, Maryland.

NOLC. Naval Ordnance Laboratory, Corona, California.

NOLO FLIGHT. The flight of a **drone** without a human (safety) pilot aboard.

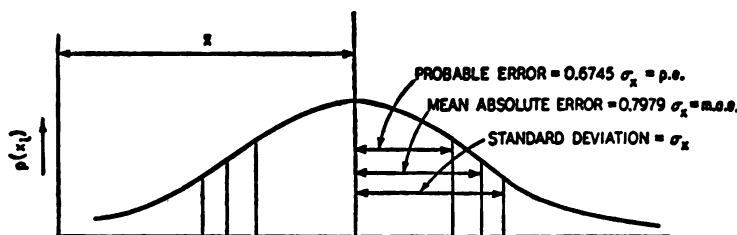
NOMINAL BOMB. A bomb whose energy release is equivalent to that of 20,000 tons of TNT, referred to as a 20 KT (Kiloton) bomb. (Such a bomb was used against Hiroshima in World War II.)

NONATMOSPHERIC CONTROL. Any device or system designed or set up to operate a guided missile, rocket or the like outside the atmosphere or in regions where the atmosphere is of such tenuity that it will not affect aerodynamic controls; the control provided by such devices or systems. Some of the systems used to accomplish nonatmospheric control

NORMAL DISTRIBUTION (GAUSSIAN). The distribution of random variables found frequently in nature. The principal characteristics of the Normal Law are:

- (a) It is symmetrical. Negative and positive deviations of equal magnitude are equally likely to occur.
- (b) It is a continuous function rather than a discrete function. It assigns a definite probability to every finite deviation. There are no excluded cases.
- (c) There is just one most probable result, and this is identical with the first expectation of the variable.

(See figure.)



Illustrating normal distribution and relation of probable error, mean absolute error, and standard error.

incorporate vanes or fins directly in the jet stream; others are based on the swivelling or gimbaling of the entire rocket motor, or the use of exhaust ports to direct the exhaust in such a manner as to change the course.

NON-COOPERATIVE SYSTEMS (INSTRUMENTATION). Instrumentation systems characterized by transmission of data from the airborne missile equipment to a ground station where the data are recorded: e.g., **telemetry**, **photo-theodolites**.

NONISOELASTIC (ANISOELASTIC) EFFECTS. A source of drift in **gyroscopes** caused by mass unbalance and non-linearities resulting from a lack of isoelasticity in materials.

NON-ROTATING EARTH. A mathematical artifice used in computing performance characteristics of long-range **ballistic missiles**. The trajectory equations are simplified because of omission of the effects of **Coriolis acceleration**, earth oblateness, and **gravitational anomalies**.

NORAD. North American Air Defense.

NORMAL FORCE COEFFICIENT. The proportionality factor of the component of force on an aerodynamic body as resolved into a direction normal to the direction of motion of the body. It is a theoretical concept useful in computation of aerodynamic effects. (See also **coefficient of force** and **longitudinal force coefficient**.)

NORMAL LAPSE RATE. The average rate of decrease in temperature with increase in altitude. The normal lapse rate is 3.3°F decrease per 1,000 feet of altitude. (See **standard pressure lapse rate**.)

NORMAL MODES OF VIBRATION. Coupled modes.

NORTH. True north. See also **compass north**, **grid north**, **magnetic north**.

NORTH AMERICAN AIR DEFENSE. A coordinated defense of North America against air or missile attack.

NORTH MAGNETIC POLE. Magnetic pole.

NORTHERN LIGHTS. Auroral displays of multicolored illumination appearing in the

skies above the arctic regions. These displays occur at altitudes of 35-700 miles above the earth, and are believed to be caused by rarefied gases of the upper atmosphere upon excitation by streams of ionized particles ejected by the sun and "captured" by the earth's magnetic field.

NOSE. (1) The forward point or section of an aircraft, of an airplane's fuselage. (2) The foremost point or section of a bomb, guided missile, etc. (3) A feature of a radar beam that appears when the beam is radiated in a direction where maximum intensity is manifested. (4) The leading edge of an airfoil.

NOSE CONE. (1) A generic term for the separable payload portion of a long range ballistic missile. The nose cone includes the warhead, fuzing system, stabilization system, heat shield and supporting structure and equipment. (2) The payload of a research test vehicle.

NOTCH FILTER. (1) Any band-rejection filter which produces a sharp "notch" in the transfer characteristic of a system. (2) A filter employed in a television transmitter to provide attenuation at the low-frequency edge of the channel to prevent possible interference with the sound channel of the lower adjacent channel.

NOTS. Naval Ordnance Test Station; China Lake, California.

NOVA. There is probably no class of stars that attracts so much popular attention as the novae or "new stars." These objects suddenly appear in the sky at unpredicted time and place, in some cases becoming the brightest

object in the sky for a few days. They then fade away and disappear from naked-eye observation, but may be followed telescopically for indefinite lengths of time. Many novae which do not attain naked-eye brilliancy are discovered and studied telescopically. It is impossible to give a definite estimate of the total number of novae which appear each year, for undoubtedly many escape detection. Bailey has estimated that 10 or more reach a brightness of the ninth **stellar magnitude** or greater each year. During the first 35 years of the present century there were 5 novae which reached conspicuous brightness.

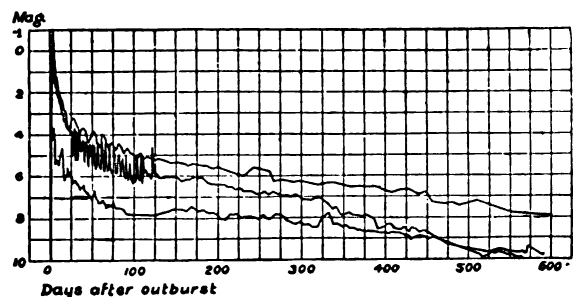
In the accompanying figure we have represented the **light curves** of three of the bright novae of the present century. The ordinate scale of brightness is expressed in stellar magnitude, and, since magnitude 6 is the limit of naked-eye visibility, the length of time that each was visible to the naked eye may be determined from the time scale at the bottom. These curves are characteristic of most novae, with the very rapid rise to maximum and then the relatively slow and irregular decline. Examination of photographic records indicates that novae are not actually "new stars" at all, but rather are faint stars which, for some unexplained reason, suddenly increase in intensity. An increase of 10 magnitudes is by no means uncommon, and this represents an increase of light intensity amounting to 10,000 fold.

NOVAL. The basing arrangement for a nine-pin, miniature, glass **vacuum-tube**. The tube pins extend directly through the glass envelope.

NOZZLE. A duct, tube, pipe, spout, or the like through which a fluid is directed and from the open end of which the fluid is discharged, designed to meter the fluid or to produce a desired direction and type of discharge. For example, a jet nozzle for a jet engine or rocket, i.e., its thrust-producing constriction.

NOZZLE ANGLE CORRECTION FACTOR.

A factor used to correct the theoretical thrust developed by a rocket motor. It is necessitated by the divergence of the motor nozzle causing the velocity vectors representing the ejection thrust to diverge from their normal backward direction. The nozzle angle correction factor is proportional to the exit angle of the nozzle, and is given by the formula:



Light curves of Nova Aquilae, 1918; Nova Persei, 1901; and Nova Geminorum, 1912. They are designated in order of decreasing height. (*Harvard College Observatory Annals*.)

$$\lambda = \frac{1}{2} + \frac{1}{2} \cos \alpha$$

where λ is the nozzle angle correction factor, and α is the nozzle exit angle.

NOZZLE AREA RATIO. In rocket motor design, it is desirable theoretically that the pressure of the exhaust gases leaving the nozzle be identical in pressure with the surrounding medium. This means that the expansion in the exhaust nozzle must be determined by proper design, for this expansion determines the final pressure of the gases leaving the motor. The nozzle area ratio is the ratio between the nozzle exit cross-section and the throat cross-sectional area. The value of this ratio which causes p_e to equal p_o is given by:

$$\epsilon = \frac{A_e}{A_t} = \frac{\left[\frac{2}{\gamma + 1} \right]^{\frac{\gamma + 1}{2(\gamma - 1)}}}{(p_o/p_e)^{\frac{1}{\gamma}} \sqrt{\frac{2}{\gamma - 1} [1 - (p_o/p_e)^{\frac{\gamma - 1}{\gamma}}]}}$$

where ϵ is the nozzle area ratio, A_e is the area at the exit, and A_t is the area at the throat.

NOZZLE BOX. A collector ring surrounding the turbine wheel of a **turbosupercharger**, containing a series of nozzles through which the exhaust gases from the engine pass to drive the turbine wheel.

NOZZLE CANT ANGLE. The angle which its nozzle axis makes with the centerline of a **jato** at the **jato cant point**.

NOZZLE, CANTED. Canted nozzle.

NOZZLE COEFFICIENT. Thrust coefficient.

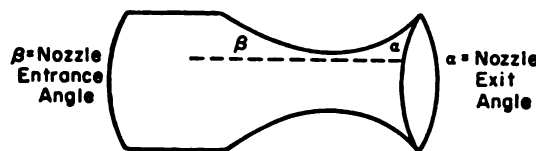
NOZZLE DIAPHRAGM. In a **turbojet engine**, a semipartition separating the **combustion chambers** from the turbine wheel, consisting of two circular bands one within the other, with equally-spaced blades between the bands, forming nozzles through which the gases pass from the combustion chambers to drive the turbine wheel.

NOZZLE DIVERGENCE. The flow in a divergent nozzle cannot be considered one-dimensional at the usual nozzle half angles exceeding 10 degrees. The acceleration of the gas particles normal to the motor axis must be taken into consideration. Consequently, the velocity vector of the jet varies over the

nozzle exit area. This variation includes changes in direction as well as changes of the scalar value, due to the energy required for normal acceleration.

NOZZLE EFFICIENCY. The efficiency with which a nozzle converts potential energy into kinetic energy, commonly expressed as the ratio of the actual change in kinetic energy to the ideal change at the given pressure ratio.

NOZZLE EXIT ANGLE. In rocket motors, the angle measuring the degree of divergence of the nozzle. (See figure.)



Supersonic or de Laval nozzle.

NOZZLE EXIT PRESSURE. In propulsion, the pressure measured at the point of emergence of the **jet stream**.

NOZZLE, OVEREXPOSED. A nozzle in which the working fluid is expanded to a lower pressure than the external pressure (i.e., exit area is too large).

NOZZLE, SUBSONIC. A nozzle in which the velocity of gas at the throat is less than the velocity of sound. The velocity of gas at the exit is also subsonic.

NOZZLE, SUPERSONIC. A nozzle in which the velocity of gas at the throat is equal to the velocity of sound. The velocity of gas at the exit is supersonic.

NOZZLE THROAT. The narrowest part of a converging-diverging nozzle.

NOZZLE, UNDEREXPANDED. A nozzle in which the working fluid is discharged at a pressure greater than the external pressure (i.e., the exit area is too small and expansion continues outside the nozzle).

Np. Neptunium.

NPSH. Net positive suction head.

NR. Noise ratio.

NRC. National Research Council.

NRJ-1. British **Napier** ramjet combustion test vehicle. It was not a missile, but an air-dropped test model designed and built by the National Gas Turbine Establishment during the early post World War II period. It was approximately 20 feet long and 18 inches in diameter, with a single stabilizing airfoil.

NSA. National Security Agency.

NSC. National Security Council.

NSF. National Science Foundation.

NSS. National Stockpile Site.

NUCLEAR BREEDER. A nuclear reactor in which more fissionable material is formed in each generation than is used up in fission.

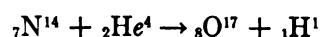
NUCLEAR ENERGY. Energy released in nuclear reactions.

NUCLEAR FISSION. Fission, nuclear.

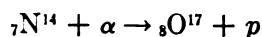
NUCLEAR FUSION. Fusion, nuclear.

NUCLEAR RADIATION. Any or all of the radiations emitted as a result of a nuclear transformation. The radiations include **gamma radiation**, and particle radiation (e.g., **alpha particles**, positive and negative **beta particles**, and **neutrons**).

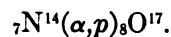
NUCLEAR REACTION. An induced nuclear disintegration, that is, a process occurring when a nucleus interacts with a photon, elementary particle, or another nucleus. In many cases the reaction can be represented by a symbolic equation similar to the following:



or in the form:



or in the form:



NUCLEAR REACTOR (Commonly only REACTOR). Reactor, Nuclear.

NUCLEAR ROCKET. A rocket propelled by nuclear energy. A model of a hypothetical nuclear rocket-powered spacecraft was recently released by the National Aeronautics and Space Administration. The illustration facing Page 539, shows a layout similar to

that used in the **electrical** propulsion vehicle, except that spherical tanks contain the propellant (liquid hydrogen), with shields to protect them from direct solar radiation and reactor heat.

NUCLEAR ROCKET ENGINE. Rocket engine.

NUCLEONICS. The science dealing with the structure, properties and reactions of the **nucleus** of the atom.

NUCLEUS. The positively charged core of an atom that contains the major portion of its mass and the total positive electric charge. Its diameter is about 1/10,000 of the diameter of the atom; including its orbital electrons.

NULL. Zero, or without action; or, in the case of an instrument, without giving a reading.

NULLO FLIGHT. In U.S. Air Force terminology, the flight of a **drone** when performing an assigned support mission rather than a simple remote-controlled test flight. (See **nolo**.)

NUSSELT NUMBER. The non-dimensional parameter, defined as

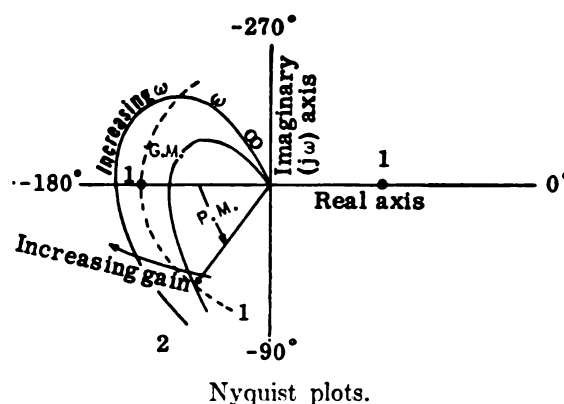
$$N_u = \frac{Q}{\Delta T k}$$

where Q is the heat loss or **heat transfer** from a solid body, ΔT is the difference of temperature between the body and its surroundings, d is the scale size of the body, k is the thermal conductivity of the surrounding fluid. The Nusselt number is useful in the reduction of measurements of free and forced convective loss of heat either from the same body in different conditions or from different bodies of geometrically-similar shapes.

NUTATION. (1) In the case of a spinning top or gyroscope, the inclination of the top's axis to the vertical will vary periodically between certain limiting angles. This motion is called nutation. In general, a spinning top or gyroscope experiences both nutation and **precession**. (2) The oscillation of the spin axis of a two-axis gyro initiated by displacement of the base or frame (airframe). It continues with a definite frequency until the disturbance is dissipated and is least pronounced when the gimbals are at 90° . (3)

The orbiting motion (usually wobbling) of a vertex feed at the focus of a paraboloid radar antenna to provide a steady plane of polarization. (4) In astronomy, the small changes in direction of an axis of rotation or revolution due to perturbations, e.g., of the earth's polar axis.

NYQUIST CRITERION. A useful parameter in servomechanism theory; it is the open-loop harmonic response function $Y_0(j\omega)$, and is based upon the properties of functions of a complex variable. A technique used for analyzing operating characteristics of closed loop control systems. (See figure.)



O

O. Oxygen (O).

O PLAN. Operation Plan.

OAL. Ordnance Aerophysics Laboratory; Convair; Daingerfield, Texas.

OBJECTIVE. In an optical instrument, the lens or system of lenses which first receives the light. It may or may not be the lens nearest the object observed.

OBLIQUE SHOCK WAVE. A shock wave forming an oblique angle with the line of flight that is greater than that of the Mach wave. The velocity of air passing through the oblique shock wave decreases more than the theoretical value through the Mach wave.

OBOE. A radar navigation and blind-bombing system using two ground stations measuring distance to a radar beacon carried by an aircraft.

OBTURATION. The prevention of loss of propelling gases backward through the breech of a cannon. An obturator is normally a leather packing gland on the breech, which is compressed against the aperture by the chamber pressure, thereby blocking blow-back.

OC CURVE. Operating Characteristic Curve for Acceptance of Sampling Plans.

OCCLUDED FRONT. Occlusion.

OCCLUDED GAS. Absorbed or adsorbed gas, particularly gas on the surfaces within vacuum tubes, whence it must be removed in manufacture.

OCCCLUSION. (1) A condition of uniform molecular adhesion between a precipitate and a soluble substance, or between a gas and a metal, of such a nature that it is very difficult to separate the occluded substance by washing or other simple mechanical process. Occlusion in precipitates depends upon the distribution of a substance between solvent

and solid and is probably due to **adsorption**. Another type of occlusion is that of hydrogen by palladium, which was studied by Graham. (2) In meteorology, when one front overtakes another, forcing one of the fronts upward from the surface of the earth, that front is said to be an occluded front, and the zone in which this condition exists is called the occlusion.

OCCULTING LIGHT. An intermittently operating light that is lighted for periods of equal or greater duration than the dark periods.

OCLUS. Outside Continental United States.

OCOSPHERE. The portion of an atmosphere which supports life, primarily from the point of view of the oxygen supply for man. In the earth's atmosphere, it extends to approximately 12,000 feet.

OCTAL BASE. An eight-pin tube-base (some pins may be omitted if unused) with a center aligning key.

OCTANT. An instrument similar to a sextant, but constructed with its arc graduated in degrees for an eighth of a circle. Frequently called a "sextant."

OCTAVE. Interval between two frequencies having a ratio of two to one. It is the logarithm to the base two (3.322 times the logarithm to the base 10) of the frequency ratio.

OCTAVE FILTER. Filter, octave.

ODOGRAPH. A device used to measure and record distance traveled. As used in the military service, the odograph is an electronic device used in trucks or other vehicles for automatic distance and direction recording. The device is used for map making and navigating over land. By means of it, any path once traveled by the machine can easily be followed again or reproduced in scale for the production of route maps, etc.

OERLIKON-CONTRAVES-BOELKOW COBRA. Cobra.

OERLIKON TYPE 54. An antiaircraft (surface-to-air) missile made by the Oerlikon Machine Tool Works (Buehrle and Company), of Zuerich in Switzerland. It was a supersonic missile 19.7 feet in length and 1.31 feet in diameter, with a wing span of 4.2 feet. Its weight (fueled) was 772 pounds, 331 pounds of which was propellant. The weight of the payload has not been disclosed. The motor delivered 2205 pounds of thrust over a 30-second burning time. Velocity of the missile was not given. Its useful range was 15.5 miles. Propellants used were white fuming nitric acid and kerosene. Compressed nitrogen at 4410 psia was used for propellant feed. The missile used a beam rider type of guidance. Four cruciform wings of delta shape were displaceable in flight according to a pre-determined time program to compensate for shift of CG (with propellant burning) and CP (with velocity). The rocket motor was gimbaled to obtain control response by thrust deflection.

Oerlikon also produced an air-to-air rocket having a diameter of 3.15 inches (8 cm) and a length of approximately 24 inches. The launching weight of approximately 22 pounds included a warhead of approximately 2.2 pounds. Three versions of this were produced: (1) with HE and contact fuze, (2) armor piercing with percussion fuze in the base of a hollow shaped charge, and (3) a practice rocket with a dummy head. A proximity fuze was considered which would include a small turbine generator, driven by the propulsion gases as a power source for a minute radar to measure continuously the distance to the target and to detonate the warhead at the proper range. It used a solid propellant rocket.

Oerlikon is the manufacturer of the famous and widely used 20mm cannon (World War II). An earlier version is identified as Oerlikon-Contraves Type 50. Subsequent improvements appeared as "Type 56" and "Type 57."

OERSTED. A unit of magnetic field strength in the emu system. The magnetic field produced at the center of a plane circular coil of one turn, and of radius one centimeter, which carries a current of ($\frac{1}{2}\pi$) abamperes.

OFF LOAD. In propellant loading, it is sometimes necessary to adjust gross weight or center of gravity. This is accomplished by off loading.

OFFENSIVE MISSILE. A missile which can be used in a tactical offensive situation, e.g., an air-to-surface missile; in contradistinction to a defensive missile, e.g., a surface-to-air missile.

OFF-RANGE. In missile proving ground usage, a term referring to either of the directions in the horizontal plane perpendicular to the flight plane, either to the left or right when looking from the launch point to the target point. The off-range direction is either the "Y" or "Z" coordinate direction, according to the convention and is positive to the right. Negative values are to the left looking down-range.

OFF-TARGET JAMMING. Jamming, off-target.

OFFSET YIELD STRENGTH. The yield strength of a material determined by the departure of the actual stress-strain diagram from the initial straight line relation of stress and strain. (Frequently taken as 0.002 in. per in.) (See **elasticity**.)

OGIVE. (1) A solid of revolution whose contour is an arc of a circle. (2) An ogive whose center of arc is in the plane of the base of the nose (thereby creating no break in the contour when attached to a cylinder at its base, that is, the surface joins the cylindrical surface on the tangent) is defined as a *tangent ogive*. An ogive generated by an arc not tangent, but intersecting at a small angle a segment which forms the cylindrical surface is a *secant ogive*. It may have any radius of curvature greater than that of the tangent ogive on up to an infinite radius of curvature (i.e., a straight, conical ogive) but, unless otherwise specified, a secant ogive has approximately twice the radius of curvature of a tangent ogive.

An ogive generated by a line segment plus an arc of infinite radius is a *conical ogive* (i.e., a cone plus a cylinder).

OHM. A unit of electrical resistance, symbol, Ω . (1) The absolute ohm is defined as the resistance of a conductor which carries a steady current of one absolute ampere when

a steady potential difference of one absolute volt is impressed across its terminals. This is equivalent to the statement that the conductor dissipates heat at the rate of one watt when it carries a steady current of one absolute ampere. The absolute ohm has been the legal standard of resistance since 1950. (2) The International ohm, the legal standard before 1950, is the resistance offered to a steady electric current by a column of mercury of 14.4521 gm mass, constant cross-sectional area, and a length of 106.300 cm, at 0°C.

$$1 \text{ Int. ohm} = 1.000495 \text{ abs. ohm.}$$

OHM LAW. This very familiar law of **electric conduction**, stated by George Simon Ohm in 1827, is expressible in various forms, of which the following is typical: The steady electric current in a metallic circuit is proportional to the constant total electromotive force operating in the circuit: $I = KE$. The constant K , known as the "conductance" of the circuit, is the reciprocal of the **resistance** R ; so that the equation may be written in the more usual form

$$I = \frac{E}{R}.$$

Emphasis must be placed on the constancy of the electromotive force and the current. For, if the current varies, the effects of **inductance** and **capacitance** set up extra electromotive forces, positive or negative, which render the law expressible in general only by a differential equation. Also there are certain kinds of conduction for which the law is not valid; notably that of ionized gases, thermionic vacuum tubes and photoelectric cells.

OHMMETER. An instrument for the measurement of electrical resistance.

OJT. On-the-Job Training.

OMNIBEARING. A bearing toward an omnidirectional **radio-range station**.

OMNIBEARING-DISTANCE NAVIGATION. A form of radio navigation using a polar coordinate system as a reference, making use of **omnibearing-distance** facilities.

OMNIDIRECTIONAL ANTENNA (OR BEACON). Antenna, **omnidirectional**.

OMNIDIRECTIONAL RADIO RANGE. A radio range giving bearings in all directions from its transmitter.

ON 7030. An **oxidizer** used in combination with fuels in propulsion systems, and consisting of 70% nitrogen tetroxide and 30% nitric oxide.

ONE-AND-A-HALF STAGE MISSILE. A **ballistic missile** which stages part of the booster system, but retains the basic tankage and other equipment. The main feature is that the sustainer engine is started on the ground (in contrast to a two-stage missile).

ONE-DIMENSIONAL FLOW. Flow in which all aerodynamic properties are assumed to be uniform over any cross-section normal to the flow direction. The concept of one dimensional flow assumes that the aerodynamic quantities vary extremely slowly in all directions but one; consequently the parameters become functions of only one dimension. One-dimensional flow theory can be applied to more general flows if the flow can be broken down into stream zones in which the conditions approximate the one-dimensional conditions. The problem is to find the boundaries of these zones, or tubes, since across them the parameters (chiefly velocity, pressure, density and temperature) are assumed constant.

ONI. Office of Naval Intelligence.

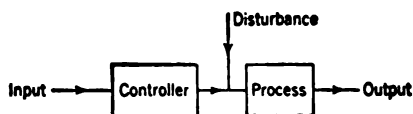
ONR. Office of Naval Research.

OPACIFIER. A compound added to a solid propellant to prevent ignition of the propellant behind its burning surface by intense radiation from the flame in the combustion chamber. The grain is translucent and, in the absence of the opacifier, transmits the radiant energy back into the charge, so that a minute flaw could absorb the radiation and become ignited. Its internal burning might cause the charge to break up and expose excessively large burning surfaces, resulting in dangerously high chamber pressures, and possible explosion. An opacifier also protects a propellant from storage deterioration.

OPDEVFOR. **Operational Development Forces.** A U.S. Naval Task Force for the evaluation of new weapon systems.

OPEN CYCLE CONTROL SYSTEM. In servomechanisms, a form of control which is not closed loop, i.e., in which the output is not fed back to the input for refinement of response.

OPEN LOOP. A control system in which there is no self-correcting action for departure from the target value, as there is in a closed loop system. (See figure.)



Basic elements of an open-loop system.

OPEN LOOP TESTING. A test technique characterized by lack of a **feedback** path. (See **go-no-go testing**.)

OPEN ORBIT. Orbit, open.

OPERATING CHARACTERISTIC CURVE FOR ACCEPTANCE SAMPLING PLAN (OC CURVE). A curve showing the relation between the probability of acceptance and either lot quality or process average quality, whichever is applicable.

OPERATIONAL. A status of evolution of a system or weapon which permits its use by field forces for tactical or strategic applications. Generally, operational missiles are supplied from follow-on production to the development missiles.

OPERATIONAL AMPLIFIER. A computer component which performs a mathematical operation, e.g., addition, division, etc.

OPERATIONAL CAPABILITY. The extent to which a system or weapon can fulfill its assigned operational mission.

OPERATIONAL CONCEPT. A general over-all statement of approved military policy pertaining to a specified weapon system, and containing the guidance necessary for the preparation of the logistics, installations, and personnel concepts, and the operations plan for that weapon system. The operational concept contains such information as a general description of the weapon system and its application, the organizational structure, the operational capabilities and the utilization of the system, the communications and electron-

ics associated with the system, and the theater and the time deployment for the system.

OPERATIONAL DEVELOPMENT FORCES (OPDEVFOR). A naval force responsible for tactical evaluation of missiles, weapon systems, and other Naval Ordnance, under fleet operating conditions.

OPERATIONAL MISSILE. A missile that, in contrast to a research and development missile, can be used to attack an enemy target.

OPERATIONAL READINESS. Probability that a system will perform satisfactorily at any point in calendar time. (Same as Up-Time.)

OPERATIONAL REQUIREMENTS. Requirements, operational.

OPERATIONAL RESEARCH. Research, operational.

OPERATIONAL SUITABILITY. A term descriptive of a weapon system which is capable of implementing an operations plan.

OPERATIONAL SUITABILITY TESTING. According to U.S. Air Force research and development terminology, the expression operational suitability testing (OST) denotes the various tests and evaluations of equipment with its components, support items, and personnel skills under actual or simulated combat and climatic conditions with the following objectives: (1) To determine suitability as a weapon system or as an integral part of a weapon system or support system for operational employment; (2) To develop the most effective operational tactics and techniques; (3) To obtain supplemental data and refine the rate of parts consumption, maintenance, and other support requirements data obtained during research and development tests; (4) To obtain supplemental data, and to refine organizational and personnel skill and training requirements obtained during the research and development tests; (5) To determine the adequacy of tables of organization and master equipment allowance lists.

OPERATIONS ANALYSIS. Research, operations.

OpNav. Office of the Chief of Naval Operations.

OPPOSITION. A phase difference of one-half cycle.

OPTIC, AXIS. A direction through a doubly-refracting crystal along which no double refraction occurs. A uniaxial crystal has one such direction, a biaxial has two such directions.

OPTICAL AXIS. The line through the **foci** and the **vertices** of the optical surfaces. Commonly, the surfaces of lenses and mirrors are figures of revolution about the optical axis. Normally, the parts of an optical system are all coaxial.

OPTICAL INSTRUMENTATION. Any form of proving-ground data collection equipment using optical means for the collection of information. Photography is the most widely-used source of missile data, since it provides the necessary precision for accurate position measurement, as well as time-correlated attitude and general observation of the missile flight. It is also independent of any internal missile equipment failures. Missile trajectories can be re-constructed by the application of photogrammetry, i.e., optical triangulation using two or more cameras at the ends of a known base line covering the same flight period. Although visibility conditions limit the usefulness of optical instrumentation, its flexibility insures its continued usage on missile test ranges. The optical instruments include fixed-plate cameras (i.e., **ballistic cameras**), **phototheodolites**, **tracking telescopes**, ribbon frame cameras, motion picture cameras and many other cameras. In the broad sense of the term, optical instrumentation also includes such instruments as **interferometers**, photomultiplier tracking stations, etc. Cameras are used to accomplish the following data missions: documentary photography, engineering sequential, engineering surveillance, and metric trajectory measurement (using both fixed and tracking cameras).

OPTICS. Originally that branch of physical science which treats of the phenomena of light and of vision. Today, because of the constantly increasing importance of ultraviolet and infrared radiation, optics has come to include all phenomena associated in any way with electromagnetic waves with wavelengths greater than x-rays and shorter than micro-

waves. Numerical limits of this wavelength region are not definitely defined.

Since the advent of devices such as the electron microscope and the **cathode ray tube**, in which beams of particles are focused to form images, the study of the behavior of such instruments is also called optics, usually with an appropriate modifier.

OPTIMIZATION (OPTIMILIZATION). The approach to economically perfect design or operation, accomplished primarily by analytical rather than "hit or miss" methods.

OPTIMUM HEIGHT OF BURST. The calculated height of burst above the earth's surface, or above a target, at which a nuclear weapon should be detonated in order to produce a particular effect over the greatest possible area.

ORBIT. (1) A line described by a body or vehicle moving about a point. This definition is general, and applies to cases in which no attractive force is implied, such as the case of an airplane moving about a place on the surface of the earth. (2) However, the use of the term orbit in astronautics is restricted to cases in which the moving object is attracted to the point, and usually the attraction is further restricted to gravitational attraction. Thus, an orbit in this sense is simply the path of a body acted upon by **gravitation**.

ORBIT, CLOSED. A circle or ellipse in a central force field (invariant elements).

ORBIT, COMET. Orbit with an initial, but not a final, restraint, such as used by instrumental comets.

ORBIT, CONIC. Orbit in a central force field (orbital elements are invariant).

ORBIT, DISTURBED. Orbit in a non-homogenous gravitational field. Such an orbit is not a truly closed orbit (its elements vary).

ORBIT, OPEN. Circle or ellipse in a perturbed field (with changing elements).

ORBIT, SATELLITE. Closed orbit about a celestial body as the center of attraction.

ORBIT, TRANSFER. Line of motion characterized by initial and final constraints.

ORBITAL BOMBER. A projected bombing aircraft with the capability of near-orbiting speeds to allow the craft to circle the earth one or more times at very high altitudes and then glide back to base.

ORBITAL ELEMENTS. In celestial mechanics, the six parameters which define the orbital geometry and motions of a body in elliptical orbital motion. (See **satellite elements**; **planetary motion**.)

ORBITAL GLIDER. A vehicle that achieves sufficient velocity to attain an altitude so as to revolve about the earth a desired number of times before falling (or gliding) back to earth.

ORBITAL ROCKET. A rocket with sufficient range and speed to achieve an orbit about the earth.

ORBITAL VELOCITY. Velocity, orbital.

ORBITON. Rocketon.

ORD. Operational Ready Date.

ORDCIT. Ordnance, California Institute of Technology; Pasadena, California.

ORDIR. Columbia University's 2,500 mile range radar set. The name was derived from omnirange digital radar (for long range missile detection). It operates in the 3,000 mc/s range. The extra range was stated to be obtained by use of a so-called "tagged" signal. The public statement made indicated that the wave was not deformed but "alternately crowded together and spaced widely over a given time interval for purposes of identification." The exact circuitry is still classified.

ORDVAC. A high speed digital computer located at the Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland. It has an IBM card input and output.

ORGAN, END (obsolescent). An end instrument, pickup, or transducer; a device for measuring a quantity for transmission by a telemetering system.

ORGAN PIPE RESONANCE. A resonant organ note produced in a jet engine diffuser-tail pipe under certain conditions of gas flow. It is often accompanied by overheating and therefore is to be avoided.

ORGANIZATIONAL MAINTENANCE. Maintenance, organizational.

ORI. Operational Readiness Inspection.

ORIENTATION. (1) In photogrammetry, a set of quantities which fixes the position of the camera station and the angular direction of the camera. Such a set consists of three elements of position and two elements of angular orientation. The elements of position are usually expressed as three rectangular coordinates, "X," "Y" and "Z," while the angular elements are the tilt of the camera above or below the horizontal and the azimuth in which it points. (A complete orientation might also include the angular rotation of a camera about its optical axis, in cases where the camera is turned out of the horizontal to permit use of the corners of the frame or plate.) *Relative orientation* is the reconstruction of the same perspective conditions between a pair of photographs as existed for the cameras when the pictures were taken. *Absolute orientation* fixes the scale, position, and orientation of the photographs with reference to the ground coordinates. (2) In artillery usage, the process of orientation is the establishing of the direction of a line-of-sight for a piece of ordinance (or a radar beam), on the point to satisfy certain alignment conditions. These pointing conditions include parallel setting of two lines of sight (e.g., between the line-of-sight indicated on the radar set and the true azimuth to the reference point), convergence at some fixed distance for the lines of sight, or alignment of electrical with optical axes. This latter is more properly termed "collimation," but in some usages collimation is included in the more inclusive term orientation. (3) In strict military terminology, orientation is merely the process of causing an instrument to read true. (4) In radio-controlled missiles, orientation includes the establishment of the proper direction to the guidance beam, and the adjustment of it to compensate for various geodetic effects (e.g., **Coriolis effect**.)

ORIENTATION ANGLE. The angle between rocket axis and launcher line.

ORIFICE. An opening through which a fluid may discharge. The pressure drop across orifices of standard forms is used to measure flow of fluids along pipes and channels.

ORIOLE. (1) A U.S. Navy air-to-air missile by the Glenn L. Martin Co. It was cancelled

at the prototype stage. (2) A U.S. Navy project (1957), using a **Terrapin** and a **Loki** in a 2-stage combination to reach a 100-mile altitude. The Oriole was planned to carry explosive payloads to this altitude, where detonation would throw out steel pellets at or near **escape velocity**. (See **missile, guided**.)

ORION. This **constellation** is, on the whole, the most impressive of all of the constellations. Despite the wide area covered, the physical characteristics of many of the stars are so similar that there is considerable evidence in support of the theory that they have a common origin.

The star Betelgeuse must be considered as an exception to this class for it is quite different from the other bright members of the constellation. Its color is a distinct yellow-orange as contrasted with the blue-white tint of the typical "Orion star." It is a **giant star**, its diameter, as measured with the interferometer, being about 300 times that of the sun.

The middle "star" of the sword is not a star at all, but is a huge gaseous **nebula**. This is one of the very few nebulae that can be seen with any satisfaction in a small instrument. (See also **Bold Orion**.)

ORT. Operational Readiness Test.

ORTHICON. A camera tube (see **tube, camera**) in which a low-velocity **electron-beam** scans a photoactive mosaic which has electrical storage capability.

ORTHICON, IMAGE. Image orthicon.

ORTHOGONAL. The property of being at right angles, or, more generally, independent, e.g., the X, Y, and Z directions, or the R, ϕ and θ directions in polar coordinates are orthogonal. Functions represented by the electric intensities of two radio signals, the ratio of whose frequencies is irrational, are orthogonal.

ORTHOGRAPHIC PROJECTION. A map projection made so that features of the globe are presented as they actually would appear if viewed from a point in space located at mathematical infinity, so that true perspective is maintained.

Os. Osmium.

OSCILLATION. A periodic phenomenon: e.g., in **servomechanisms** a periodic change of the controlled variable.

OSCILLATION, FORCED. The oscillation which results when an external periodic driving force is applied to a system capable of free oscillations. In the one-dimensional case for a dissipative system the differential equation of motion is

$$m \frac{d^2x}{dt^2} + R \frac{dx}{dt} + fx = F_0 \cos 2\pi\nu t.$$

F_0 is the amplitude of driving force; ν is frequency of driving force.

The solution to this equation has two parts, a transient which eventually damps to zero, and a steady state which is the dominant part when the transient diminishes. The steady state solution has the form

$$x = \frac{F_0 \cos (\omega t - \alpha)}{\sqrt{\omega^2 R^2 + (f - m\omega^2)^2}}$$

where $\omega = 2\pi\nu$, $\alpha = \tan^{-1} \frac{R\omega}{f - m\omega^2}$ = phase

differences between force and displacement.

Of special interest in forced oscillation is the phenomenon of resonance. Velocity resonance is a state of maximum velocity and occurs when the frequency of the driving force

has the value $\nu_0 = \frac{1}{2\pi} \sqrt{\frac{f}{m}}$. ν_0 is called the

resonance frequency. Amplitude resonance is a state of maximum displacement and occurs when the frequency of the driving force has

the value $\nu_1 = \frac{1}{2\pi} \sqrt{f/m - R^2/4m^2}$.

When the damping coefficient is small, the amplitude resonance frequency ν_1 and the free oscillation frequency become approximately the same. At the resonance frequency ν_0 , the force and velocity are exactly in phase while the force and displacement are 90° out of phase. The word resonance in general usage means amplitude resonance.

OSCILLATION(S), FREE OR NATURAL.

(1) **Oscillations** that continue in a circuit or system after the applied force has been removed, the frequency of the oscillations being determined by the parameters in the system or circuit, commonly referred to as shock-excited oscillations. (2) The oscillation of some physical quantity of a body or system when the externally applied forces consist either of those which do no work, or of those which are derivable from a potential that is

invariant during the time under consideration, or both. (3) That type of oscillatory motion into which a suitable system not subject to external driving forces is capable of being excited by a displacement from an equilibrium position.

OSCILLATION, FREQUENCY OF. The number of complete **oscillations** of a given system per unit time, commonly symbolized by ν or f . The **frequency** is the reciprocal of the **period**, the time for one complete oscillation. Sometimes the **angular frequency**, symbolized by ω , is used for greater convenience in manipulating trigonometric functions. The angular frequency has the unit radian per unit time and is equal to $2\pi \times$ frequency.

OSCILLATION, PARASITIC. An unintended, self-sustaining **oscillation** at a frequency different from the operating frequency.

OSCILLATION, PHUGOID. A long-period **oscillation** characteristic of the disturbed longitudinal motion of a missile.

OSCILLATION, STABLE. An **oscillation** of constant amplitude or frequency.

OSCILLATION, STEADY-STATE. **Steady-state oscillation.**

OSCILLATION, UNSTABLE. An **oscillation** whose amplitude increases continuously until a catastrophe occurs or stabilizing forces are brought to bear: e.g., in aerodynamics an oscillation which increases continuously until an attitude is reached from which there is no tendency to return towards the original attitude, the motion becoming a steady divergence.

OSCILLATOR. (1) Any mechanical or electrical device designed to set up and maintain oscillations of a frequency determined by its physical constants: e.g., vacuum tubes, sparks, or arc generators. (2) In a superheterodyne receiver, that stage which generates a radio-frequency signal of the correct frequency to mix with the incoming signal and produce the intermediate-frequency of the receiver. (3) In a transmitter, the stage that generates the carrier frequency or a frequency equal to some definite multiple of the carrier frequency. (4) A test instrument that can be set to generate an unmodulated or tone-modulated radio-

frequency signal at any frequency needed for aligning or servicing radio receivers and amplifiers. (5) A test instrument for generating an audio-frequency signal, at any desired frequency for test purposes. (6) In early radio, a form of generator or radio transmitter. (7) In the very high and ultra-high frequencies, a generator that is coupled to some form of radiator as a transmitter.

OSCILLATOR, BACKWARD WAVE. A local **oscillator** employing a special vacuum tube in which oscillatory currents are produced by bunching electrons as they flow from cathode to anode. An oscillatory electromagnetic field is used to bunch the electrons. (Used in radar sets, signal generators, counter-measure receivers, etc.)

OSCILLATOR, BEAT - FREQUENCY (BFO). A device from which a single audio frequency is obtained by combining and rectifying two higher frequencies.

OSCILLATOR, BLOCKING. An electrical circuit used to generate very narrow pulses. The two common types are: (1) *Free running*—which determines its own repetition rate, and thus may be used as a master oscillator; (2) *Driven*—which is used to convert broad trigger pulses into sharp, short pulses (approximately 1 microsecond duration).

OSCILLATOR, COUPLED (MECHANICAL). A system with two or more components coupled by forces which can be considered either exactly or approximately as harmonic. The resultant motion of each component when the system is displaced from its equilibrium position can be considered as a linear superposition of simple harmonic oscillations with characteristic frequencies known as normal frequencies. For a non-degenerate non-dissipative coupled system of n particles each having one degree of freedom, there will exist n normal frequencies. It is theoretically possible by the correct choice of initial conditions to set a coupled system into oscillation so that all the particles vibrate with only one normal frequency. Such a vibration is called a normal mode of vibration. For the n particle system there will exist n normal modes and n normal coordinates. A normal coordinate vibrates harmonically with a single normal frequency and can be found by a transformation of the actual displacement co-

ordinates which describe the individual motion of each particle.

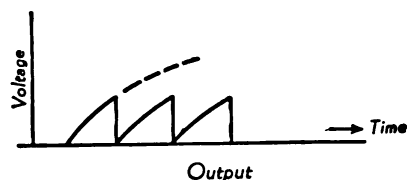
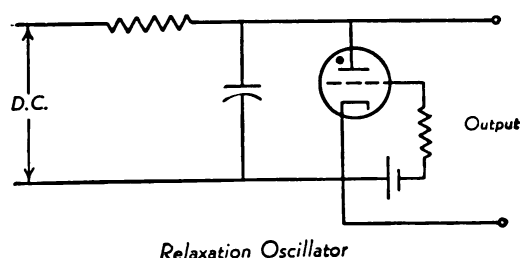
OSCILLATOR, CRYSTAL-CONTROLLED.

An oscillator using a mechanically-vibrating piezoelectric crystal with an energy transfer between a mechanical vibrating system and the electric circuit. This oscillator is used in place of a resonant circuit as a stable frequency source.

OSCILLATOR, LOCAL. An oscillator whose output is mixed with a wave for frequency conversion.

OSCILLATOR, PUSH-PULL. Push-pull oscillator.

OSCILLATOR, RELAXATION. An oscillator whose fundamental frequency is determined by the time of charging or discharging of a capacitor or inductor through a resistor, producing wave forms which may be rectangular or sawtooth. These oscillators have very distorted wave shapes, giving various outputs such as square waves, trapezoidal waves, triangular waves and pulses of very short duration. These distorted waves have made them ideal for many control and triggering purposes in more elaborate electronic circuits. The relaxation oscillator may be easily synchronized with another oscillator or other source of voltage by injecting some of the other voltage into the relaxation circuit at the proper point. A simple, but widely used, relaxation oscillator is shown in the figure.



Here the condenser is charged through the resistance until the voltage across the thyratron reaches the breakdown value when it breaks down and discharges the condenser

very rapidly. The process is then repeated and the resultant voltage output is as shown.

OSCILLATOR, SELF-EXCITED. Self-excited oscillator.

OSCILLATOR, RELAXATION. Relaxation oscillator.

OSCILLOGRAM. The record produced by an oscillograph.

OSCILLOGRAPH. A recording instrument. The basic principle of most oscillographs is the D'Arsonval movement. This is essentially a suspended coil in a magnetic field. Current passing through the coil imparts torque, while a pen is attached to the coil to produce a record.

OSCILLOGRAPH RECORDER. A device capable of charting high speed variations in measured quantities, such as temperature or pressure, as found in missile or vehicle testing.

OSCILLOSCOPE. Cathode ray tube.

OSCULATING ELEMENTS. In celestial mechanics, the theoretical orbital elements which would describe a body's elliptical motion assuming all other influences except those specified (generally the gravitational attraction of the primary and its satellite), are non-existent. In the case of an Earth satellite, osculating elements would describe an orbit in which the satellite was not influenced by geodetic anomalies or all other celestial bodies except the Earth. (See **satellite elements**.)

OSMIUM. Metallic element. Symbol Os. Atomic number 76.

OSN. Office of the Secretary of the Navy.

OSRD. Office of Scientific Research and Development.

OSS. Office of Strategic Services—Operational Storage Site.

OST. Operational suitability testing.

OSW. Office of the Secretary of War.

OSWALD AIRPLANE EFFICIENCY FACTOR. A factor used to adjust wing span from theoretical values to approximate actual values.

OSWATITSCH DIFFUSER. An annular ramjet, center-body diffuser. It consists of

a concave conical spike, formed of a succession of cones of increasing angle. This shape produces a series of oblique shock waves (see **shock waves, oblique**) of slowly-increasing angles. If there were no outer duct, this surface would focus all the wave fronts to form an intense shock wave front. This result is avoided by placing the lip of the outer duct at a point just before that at which the waves would otherwise combine into this single wave front.

OTU. Operational training unit.

OUTAGE. In a (usually ballistic) missile the propellant remaining in the tankage which cannot be used (e.g., converted into useful energy).

OUTER CONE. The casing, shaped like a truncated cone, of an exhaust-cone assembly. (See **exhaust cone**.)

OUTER LOOP. The control loop, including the missile and its guidance dynamics. This loop is outside the normal control system feedback loop which includes the aerodynamics of the missile. (See **guidance**, and its illustrations.)

OUTER SPACE. (1) Space beyond the earth's **atmosphere**. (2) Space beyond the **solar system**. (3) Space between **galaxies**.

OUTPUT IMPEDANCE. The impedance presented by the **transducer** to a load.

OUTPUT, PEAK POWER. The output power averaged over the radio-frequency cycle having the maximum peak value which can occur under any combination of signals transmitted.

OVERCAST. (1) A cloud or clouds covering all, or almost all, of the visible sky. (2) A cloud or clouds covering more than nine-tenths of the sky. (3) A cloud cover that is overhead.

OVERDAMPING. Damping which in amount is sufficient to prevent, partly or entirely, the normal oscillation of a vibrating system. When *overdamping* is applied to the vibration at maximum amplitude, the vibration will return to the zero position with no overshooting. (See also **critical damping** and **underdamping**.)

OVER-EXPANSION. The action of a rocket motor exhaust nozzle in causing the exit pressure of the exhaust gases to fall below the pressure of the surrounding medium, thus producing a suction at the mouth of the rocket motor. If the over-expansion is carried far enough, a breakdown of the flow occurs and a **shock wave** is formed. The optimum condition exists when the nozzle expands the exhaust gases to exactly the same pressure as the outer atmosphere. It can be seen that over-expansion cannot occur in space, where there are no frictional forces to limit the expansion ratio which can be tolerated. Without friction, a rocket exhaust nozzle could be expanded, for advantage in pressure **thrust**.

OVERPRESSURE. The destructive pressure in the blast wave from an explosion, usually expressed in pounds per square inch above atmospheric pressure. During some period of the passage of the wave past a point, the overpressure may be negative; that is, the absolute pressure at that point may be less than atmospheric pressure. The following damage can be expected from an air blast of the overpressure indicated:

PSI OVERPRESSURE	DAMAGE
1.0	Window glass cracks
1.5	Light damage to window frames, plaster, and complete window damage
1.8	Light damage to aircraft
2.4	Heavy plaster damage
5.2	9-inch brick wall cracked, severe damage to steel frame buildings
7.4	12-inch brick walls cracked
12.0	13-inch brick walls destroyed
24.0	10-inch reinforced walls collapsed
36.0	Decks of steel bridges shift

OVERSHOOT. An occurrence in a control system when the control process exceeds the target value as operating conditions change.

OVERSHOOT FACTORS. Aerodynamic factors which define the load applied to a surface or body as the result of maneuvers. The missile overshoots the desired angle of

attack due to control system and aerodynamic damping characteristics.

OVERTONE. (1) A physical component of a complex sound having a frequency higher than that of the basic frequency. (2) A component of a complex tone having a pitch higher than that of the fundamental pitch. (3) The term overtone has frequently been used in place of **harmonic**, the n th harmonic being called the $(n - 1)$ st overtone. There is, however, ambiguity sometimes in the numbering of components of a complex sound when the word overtone is employed. Moreover, the word tone has many different meanings so that it is preferable to employ terms which do not involve tone wherever possible. (4) In a mechanical vibrating system with a set of normal modes of oscillation (e.g., a vibrating string) an overtone is a mode of frequency higher than the fundamental. The first overtone is the mode of frequency next higher than the fundamental, etc. (See **harmonic**.)

OWI. Office of War Information.

OXIDATION. In its original use, oxidation meant simply combination with oxygen with attendant liberation of heat. Its use has, however, been considerably widened to cover a great many processes similar to oxidation, such as chlorination, and other processes of combination with strongly nonmetallic elements, which add electrons readily. In fact, the term oxidation in its broadest sense means simply a chemical reaction whereby electrons are removed from one or more of the atoms of a substance. It is, of course, most frequently accompanied by a simultaneous process, in the same reaction, whereby another substance or substances gain the electrons and thus undergo reduction; therefore, calling the process oxidation, under these circumstances, simply means that it is this part (i.e., loss of electrons) of the particular process that is of greatest interest.

OXIDIZER. A substance which furnishes the oxygen or other element which constitutes the electron-accepting reactant of an **oxidation**. In propellants, oxidizers are chosen from those elements or compounds which react most readily. Thus, there are many compounds which can be used as oxidizers. The most concentrated supply of oxygen is oxygen itself, and liquid oxygen is the most commonly

used oxidizer for liquid propellants. For solid propellants a solid compound containing available oxygen may be used. The following are some of the frequently used oxidizers in solid propellant combinations: Perchlorates: potassium perchlorate, KClO_4 ; ammonium perchlorate, NH_4ClO_4 ; sodium perchlorate, NaClO_4 ; magnesium perchlorate, $\text{Mg}(\text{ClO}_4)_2$, and others; Nitrates: potassium nitrate, KNO_3 ; ammonium nitrate, NH_4NO_3 ; Organic nitrates: glycerol trinitrate, $\text{C}_3\text{H}_5(\text{ONO}_2)_3$; diethyleneglycol dinitrate, DEGN , $(\text{CH}_2\text{CH}_2\text{ONO}_2)_2\text{O}$; cellulose nitrate, $\text{C}_6\text{H}_7\text{O}_2(\text{ONO}_2)_3$, and others; Aromatic nitro compounds: ammonium picrate, $\text{C}_6\text{H}_2(\text{NO}_2)_3\text{OH}$; trinitrotoluene, **TNT**; dinitrotoluene, and others. For liquid propellant combinations the most common oxidizers are: oxygen, chlorine trifluoride, fluorine, hydrogen peroxide, nitric acid, sulfuric acid, nitrogen tetroxide, ozone, red fuming nitric acid, white fuming nitric acid. (See also **propellants**.)

OXYGEN. Gaseous element. Symbol **O**. Atomic number 8. Oxygen constitutes about 21% of the atmosphere. In its liquid state it is used as an oxidizing agent, especially for alcohol and other hydrocarbons, but also for the amines in liquid-propellant rocket motors. (See **liquid oxygen**; **oxidizer**; **ozone**.)

OXYGEN BOTTLE. A metal bottle designed to hold oxygen for breathing at high altitudes.

OXYGEN MASK. A mask that covers the mouth, nose, and lower face, used in inhaling oxygen from a tank or bottle, or through the oxygen-supply system of a vehicle, and through which the expired gas escapes.

OXYGEN STATION. A place or point in a vehicle where an oxygen mask can be attached to the oxygen-supply system.

OZONE (O_3). An allotropic form of oxygen; used as an oxidizer in liquid **propellant** systems.

OZONOPAUSE. The upper boundary of the **ozonosphere**.

OZONOSPHERE. A region in the **stratosphere** having a relatively high concentration of ozone, occurring at a height of approximately between 15 and 22 miles, and important chiefly for its absorption of solar radiation. Sometimes termed the **Ozone Layer** or **Ozone Stratum**.

P

P. (1) Pressure (P or p), total pressure (P), vapor pressure (p), static pressure (P_0), varying pressure (p), critical pressure (p_c), pitot pressure (p_{pit}), osmotic pressure (p , but Π is preferred). (2) Power (P), plate power (P_p), input power (P_i), output power (P_o), average power (P), radiant power or flux (P). (3) Electric polarization (\mathbf{P}), polarization, surface or strength of double layer (\mathbf{P}_s), partial potential coefficient (p). (4) Electric moment (\mathbf{p}). (5) Generalized momentum (\mathbf{p}). (6) Probability (P). (7) Phosphorus (P). (8) Proton (p).

P BAND. A radio frequency band of 225 to 390 megacycles with wave lengths of 133 to 77 centimeters, respectively. (Obsolescent.)

Pa. Protactinium.

PACKAGED MAGNETRON. Magnetron, packaged.

PACKAGING. (1) *Commercial:* The art or operations required in the preparation of goods for shipment, storage, and delivery to the consumer. Involves protection against deterioration, mechanical damage, and pilferage; requires the use of container materials, and facilities for the production and handling of packages and consideration of distribution and merchandising aspects. (2) *Military:* Application or use of appropriate wrappings, cushionings, interior containers, and complete identification markings up to, but not including, the shipping container. (3) *Guided Missile:* (a) The assembly of parts, pieces and subassemblies into a package taking into consideration the environment, heat dissipation, maintenance, handling. (b) The orderly assembly of "boxes" or equipment into the missile. (c) The preparation for shipment.

PACOR. Passive correlation ranging.

PAD. (1) A nonadjustable attenuator. (2) A resistance network used in coupling two impedances. Use of resistance rather than impedance results in a power loss, but gives

coupling independent of frequency. (3) A permanent or semipermanent base, usually concrete, constructed to support a missile-launching device. It may vary from a simple stabilized area to a complex concrete facility capable of supporting extremely heavy loads, with a central area under the missile of special refractory concrete. The larger pads are equipped with conduit outlets for electrical, hydraulic, pneumatic, or other service at the launching point. Some pads even include scales to weigh the missile accurately prior to takeoff especially when volatile fuels are used.

PADAR. (Passive detection and ranging.) An electronic system designed to detect and track targets which themselves use radar. It does not need transmission from the tracking station, but uses both the direct and reflected signals from the target.

PADDER. A trimmer capacitor used to make small corrections in resonant circuits. In **superheterodyne receivers**, such capacitors are used in series with the oscillating tuning circuit to permit calibration at the low-frequency range of tuning.

PAIRED ECHO. A method of analyzing the effects of **phase distortion**, which represents the presence of a non-ideal, phase characteristic by two small echo signals.

PALLADIUM. Metallic element. Symbol Pd. Atomic number 46.

PAM. Pulse amplitude modulation.

PANORAMIC. Having a wide range of view, which may consist of a number of successive or contiguous scenes. A panoramic sight enables the viewer to see in all directions by turning it in **azimuth** and **elevation**. A panoramic camera is usually self-powered to rotate in azimuth, taking sequential pictures as it moves.

PANORAMIC RECEIVER. Receiver, panoramic.

PARABOLA. A conic section obtained by a cutting plane parallel to an element of a right circular conical surface. It is the locus of a point which moves so that its distance from the directrix equals its distance from the focus, thus the eccentricity is unity.

The standard equation in rectangular Cartesian coordinates is

$$y^2 = 2px.$$

The coordinates of its focus are $x = p/2$, $y = 0$ and its directrix is parallel to the Y -axis at $x = -p/2$. The straight line through the focus and perpendicular to the directrix is the axis of the parabola. The point where the parabola crosses the axis is the vertex. When the curve is placed in its standard position, the axis is the X -axis and the vertex is the coordinate origin.

The latus rectum of the parabola has length $2p$. Its center is at infinity, hence it is a non-central conic.

PARABOLA, CUBICAL. A plane curve represented by the equation $y = kx^3$. There is a point of inflection at the origin and the X -axis is tangent to the curve at that point.

PARABOLA, SEMI-CUBICAL. A plane curve represented by the equation $y^2 = kx^3$. There is a cusp of the first kind at the origin, where the X -axis is a double tangent.

PARABOLIC TRAJECTORY. The ideal short-range trajectory of a missile. For longer range, that is, the path of a missile in space, the geometrical curve described is an ellipse, a parabola or a hyperbola, depending on the initial velocity. All of these paths are followed exactly only under ideal conditions. For example, these space paths assume the gravitational interaction of only two bodies, e.g., the missile and the earth. Similarly, the short-range parabolic trajectories used for projectiles fired from the surface of the earth do not include the effect of the curvature of the earth, the **Coriolis effect** of its rotation or the aerodynamic effects of the atmosphere. However, the use of a parabolic trajectory is a convenient method of computing the short-range path of a projectile by applying corrections for these and other factors.

PARABOLIC VELOCITY. The velocity of a body following a parabolic orbit.

PARACHUTE. A device which can be deployed from a vehicle moving rapidly through air in order to slow it down. A parachute is usually a canopy of fabric which will "blossom" upon deployment and thereafter lower the vehicle to the earth with little or no damage. It is also used to shorten the runout of an aircraft which has just landed. The use of parachutes with missiles is a difficult problem because of their high velocities. At supersonic speeds, the structural characteristics required in the material used in the parachute are those of metals rather than fabrics. Fabrics are used, however, in the ribbon-panel parachutes, which are designed to spread open at high wind velocities, and allow part of the air to pass through them. As the speed diminishes, the ribbons spill out less and less air until they form a more or less continuous canopy at ordinary falling speeds. One of the uses of parachutes with missiles is for instrument recovery.

PARALLAX. The apparent change of position of objects due to a change of position of the observer. Parallax is often a source of error unless precautions are taken or corrections applied. For example, in taking readings of instruments employing scales and pointers, the eye of observer and the pointer should be in a line perpendicular to the scale.

The parallax of a star is a measure of the amount by which the position of the star varies with respect to relatively very distant stars, or other celestial objects, as the earth moves through half its orbit, corrections for the effects of **aberration** having been made.

PARALLAX CORRECTION FOR MISSILES. A correction required because the location of a gun director or tracking radar is remote from the gun or missile launcher. Also required for missile guidance systems which determine position at the end of launch on the basis of ballistic information.

PARALLEL CLUSTER MISSILE. Missiles in which the **sustainer** and **booster** stages are side by side contrasted to a tandem arrangement.

PARALLEL FEED. Shunt feed.

PARALLEL PLOTS. In data reduction terminology, the linearized plots of two or more functions on the same time scale for comparative purposes.

PARAMAGNETIC. Offering less reluctance to the passage of magnetic flux than does air, and hence capable of being attracted by a magnet. Paramagnetic substances have, in other words, magnetic **permeabilities** greater than 1.

PARAMETER. An arbitrary constant, as distinguished from a fixed or absolute constant: e.g., missile gross weight. Any desired numerical value may be given to a parameter.

PARAMETERS, COMPRESSIBLE FLOW. In supersonic aerodynamics, the characteristic parameters for ordinary computations are: Mach number, (M_o), Reynolds number, (Re), Prandtl number, (Pr), Ratio of specific heats, (γ).

PARAMETRIC STUDIES OF MISSILES. Systematic approach to the evaluation of effects of variables or parameters on the design and performance of a missile.

PARAPHASE AMPLIFIER. Amplifier, paraphase.

PARASELENE. Parhelion.

PARASITIC ELEMENT. A radiating element, not coupled directly to the feed line of the antenna, which materially affects the radiation pattern of the antenna.

PARASITIC OSCILLATION. Oscillation, parasitic.

PARESTHESIA. A condition of swelling, rash, cold or hot sensation, etc. one cause of which is the formation of gas bubbles in the tissues, especially those tissues directly beneath the skin.

PARHELION. A mock sun or bright spot at the same altitude as the real sun and some distance there from in a lateral direction. There are sometimes one or more of these bright spots on each side of the real sun. The phenomenon is caused by atmospheric refraction of the sun's image, and sometimes exhibits refraction colors. The same display can occur with the moon, in which case it is called a **paraselene**.

PARHOP. An instrumentation or measurement system utilizing the **Doppler** principle (without an airborne **transponder**) and depending on reflection of a continuous signal from the missile being tracked.

PARSEC. A unit of distance, the distance of a celestial object at which an astronomical unit of distance (mean distance from earth to sun or about 92,897,000 miles) subtends an angle of one second. A parsec is approximately 3.26 light years.

PART. The smallest article; a piece of equipment cannot be broken down without losing its identity, e.g., tubes, resistors, capacitors, nuts, bolts, etc.

PARTIAL SUM. In computer logic, the sum or addition of a number without consideration of the "carry." For example, the partial sum of 5 and 6 would be 1, not 11.

PASCHEN'S LAW. The sparking potential of a gas is a function only of the product of the sparking distance and the gas pressure. (Minimum sparking potential for air ≈ 340 v.)

PASS BAND (OF A FILTER). That band of frequencies which are passed with little or no attenuation.

PASSIVE ELECTRONIC COUNTERMEASURES. Countermeasures, passive electronic.

PASSIVE HOMING. Homing, passive.

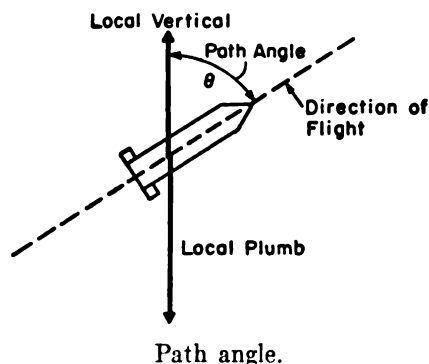
PASSIVE JAMMING. Jamming, passive.

PATCHCORD. A cord containing plugs on either end for making interconnections on a jackfield.

PATCHING. Temporary connecting of electrical circuits for the purpose of obtaining a particular output. Patching is a familiar technique in computer programming, where the interconnections differ for various problems. To facilitate patching, a board with a number of plug **jacks** and double-plugged cords for insertion in the jacks is often built into the computer. (Compare **bridging** and **switching**.)

PATH ANGLE. In ballistics, the angle between the tangent to the trajectory and the vertical. (See figure on Page 438.) It is denoted by the Greek letter theta (θ). (See also **cut-off path angle**.)

PATH CONTROL. The means by which a missile is guided through space along its **trajectory**. Components for path control are: a **tracker**, **computer**, **controller** and **effector**,



connected in that order, and usually with feedback of missile response into the tracker. In the case of inertially-guided missiles, no external tracker is required, since the missile tracks itself. (See also **attitude control**; **control guidance**.)

PATHFINDER. A payload, e.g., **beacon**, delivered into a target area by superlative guidance; the pathfinder then helping to guide less accurate missiles to the target.

PATRICK AIR FORCE BASE. A U.S. Air Force installation located near Cocoa, Florida. It is the logistic support portion of the Air Force Missile Test Center, a proving ground for long range missiles.

PAYLOAD. That portion of missile weight which is carried by the vehicle for the ultimate purpose of inflicting damage on the target. In the case of research and test vehicles, this includes instrumentation equipment for taking data and transmitting or recovering it.

Pb. Lead.

PCM. Pulse code modulation.

Pd. Palladium.

PDA. Pump drive assembly.

PDM. Pulse duration modulation. (See also **telemetering**, **pulse duration modulation**.)

p.e. Probable error.

PEAK. A high point or value, specifically the maximum value of a periodic quantity. In a sinusoidal electrical current or voltage, the peak value is the root-mean-square (effective) value multiplied by $\sqrt{2}$.

PEAK OVERPRESSURE. That maximum overpressure caused by a nuclear explosion at any given distance from **Ground Zero**.

PEAK PULSE POWER. The power at the maximum of a pulse of power, excluding spikes.

PEAK PULSE POWER, CARRIER-FREQUENCY. The power averaged over that carrier-frequency cycle which occurs at the maximum of the pulse of power (usually one-half the maximum instantaneous power).

PEAK SOUND PRESSURE. Sound (**Acoustomotive**) pressure.

PEAKING CIRCUIT. A circuit used to extend the frequency response of a video amplifier. In a shunt peaking circuit, the impedance of the load circuit of an amplifier stage is raised when a small inductance, included in series with the plate-load resistor, is caused to resonate with the circuit capacitance. In series peaking, a small inductance is included in series with the grid of the next stage. At the higher frequencies, this inductance resonates with the input capacitance of this grid, thus improving the frequency response. Both series and shunt peaking may be included in the same amplifier stage.

PECLET'S NUMBER. A dimensionless product of the Reynolds number and the Prandtl number. It is expressed by:

$$Pe = QR = \frac{C_p \rho V L}{\lambda}$$

where Pe is the Peclet number, Q is the Prandtl number, R is the Reynolds number, C_p is the specific heat at constant pressure, ρ is the density, V is the velocity, L is a typical linear dimension, and λ is the thermal conductivity.

PELICAN. A U.S. Navy glide bomb developed during World War II. It was sponsored by the National Defense Research Committee. It used a semi-active radar homing system similar to that of the **Bat**. It was used in the preliminary design of the **Bat**, and was dropped as a project in preference to the **Bat**.

PELORUS. An instrument used to measure horizontal or vertical angles. It consists of a circular plate with sights, graduated in de-

grees and free to turn about an axis at the center. It is widely used in navigation.

PENDULOUS GYROSCOPE ACCELEROMETER. Accelerometer, pendulous gyroscope.

PENDULUM, GRAVITY. Let a rigid body of mass M swing on an axis which is located at distance r above its center of mass, and with respect to which axis the moment of inertia of the body is I . This motion is mathematically not simple, but if the amplitude of swing is small, certain terms in the differential equation of motion may be disregarded and the remaining equation readily solved. The solution gives as the period of the complete oscillation in which g is the acceleration of a

$$T = 2\pi \sqrt{\frac{I}{Mgr}},$$

freely falling body. Huygens found experimentally, what may be proved theoretically, that for any given period of oscillation greater than a certain minimum there are two different distances r for which I/r , and hence T , has the same value. If these two distances are laid off on opposite sides of the center of mass, the two points resulting are "conjugate points" (center of suspension and center of oscillation). Denoting the whole distance between these points by l , the period of swing when the pendulum is suspended at either of them is

$$T = 2\pi \sqrt{\frac{l}{g}}.$$

This is the same as the period for an "ideal simple pendulum," i.e., a single particle of mass m suspended by a weightless thread of length l , for which $r = l$, and $I = ml^2$. Kater utilized this principle in his well-known reversible pendulum (see **pendulum, Kater**). It was Huygens who first adapted the pendulum to regulate a mechanism for keeping time and thereby gave us the common clock.

PENDULUM, KATER. Kater devised a number of rigid pendulums for comparing the accelerations of gravity at different places on the earth. Any pendulum of fixed length, carried from place to place, will swing in periods inversely proportional to the square root of the value of this acceleration, g , at the respective stations. Therefore if the pen-

dulum has been timed at a station at which the value of g is accurately known, its period at any field station gives at once the value of g at that station.

Kater's best known pendulum is reversible, being provided with two knife edges, facing each other, and carefully adjusted to be at conjugate points with respect to each other. It follows that when such a pendulum is accurately timed, and the distance between the two knife edges accurately measured, the value of g can be calculated by using the formula for the period T of an ideal simple pendulum:

$$T = 2\pi \sqrt{\frac{l}{g}}, \quad \text{or} \quad g = \frac{4\pi^2 l}{T^2}.$$

When this is applied to the Kater's pendulum, l is taken as the distance between the knife edges. Such a pendulum can thus be used for absolute gravity measurements. See **pendulum, reversible**.)

PENDULUM, REVERSIBLE. A pendulum which is used for accurate determinations of the acceleration of gravity. By measuring the period corresponding to two different suspension lengths, there is no need for a measurement of the moment of inertia. The acceleration of gravity is given by

$$g = \frac{4\pi^2[l_A^2 - l_B^2]}{l_A P_A^2 - l_B P_B^2}$$

where l_A, l_B are two different lengths of suspension to center of mass; P_A, P_B are periods corresponding to the above lengths.

PENDULUM, TORSION. A mechanical oscillator consisting of a cylinder suspended by a wire from a fixed support. The motion consists of a rotational oscillation of the cylinder about the suspension as an axis in a plane perpendicular to the axis. For small rotational displacements the motion is simple harmonic and has a period

$$2\pi \sqrt{\frac{I}{L_\theta}},$$

where I is the moment of inertia of the cylinder with respect to wire axis, L_θ is the restoring torque of suspension per unit deflection in radians.

PENTABORANE. A possible high energy fuel. It has the chemical formula B_5H_9 , mo-

molecular weight 63.17 lb/mole, melting point -53°F , boiling point 118°F , and specific gravity 0.61. It is somewhat corrosive and moderately toxic.

PENTAGRID CONVERTER. A vacuum tube having five grids in addition to the usual anode and cathode. It is used primarily as a combined oscillator and mixer or first detector in a superheterodyne receiver.

PENTODE. An electron tube having five elements, a cathode, plate, control electrode, and two additional electrodes which are ordinarily grids.

PERFORMANCE INDEX. Specific fuel consumption.

PERFORMANCE NUMBER. A rating number applied to fuels to express their efficiency. For example, a number $100/120$ indicates that the lean-mixture power performance is the same as 100 octane gasoline, and that its rich mixture power performance is 20% better. (See **octane number**; **cetane number**.)

PERFORMANCE SPECIFICATION. A document which defines the performance of a guided missile system as contrasted with its design requirements. Once an operational requirement has been established for a guided missile, it is then necessary to formulate a corresponding performance specification. This is a task for the materiel commands, since such a specification forms the basis of a development contract. Actually, the prospective contractor often participates in this task, depending upon circumstances. Predicted performance is derived from an operational analysis of the proposed missile and is tempered by prior experience with similar missile developments. Sometimes it is determined that performance fully meeting the operational requirement cannot be attained under the current state of the art. In such cases lesser performance is generally accepted by the operational command as an interim goal.

PERI-APSIS. Apsis.

PERIGEAL. Of or pertaining to a perigee.

PERIGEE. The point in the space orbit of a body at which it is closest to the earth. In the case of a missile which returns to earth,

and whose trajectory, if elliptical, is partly inside the earth (theoretically), the perigee may also be inside the earth. For an artificial satellite, the perigee is the lowest point of the trajectory (contrast **apogee**).

PERIGEUM. In astronautics, the locus of points of position of a body in celestial motion about the earth, hence the track of an artificial satellite.

PERIHELION. The position in the orbit of a celestial body, especially the earth, or of a circumsolar vehicle, at which it is closest to the sun.

PERIOD. The time between each repetition of a recurring phenomenon, e.g., in a vibratory system, between successive passages in the same direction across the position of rest. Mathematically, the period is the reciprocal of frequency.

PERIOD LUMINOSITY LAW. Cepheids.

PERIOD, NATURAL. The period of a free oscillation of a body or system. (See **oscillation, free**.)

PERIODIC SYSTEM. An arrangement of the elements in a systematic grouping wherein elements having like properties occur in related positions, as in horizontal or vertical sequence, so that unknown properties of known elements, and even properties of unknown elements, can be deduced from their positions in this arrangement. The arrangement of the elements in the system is based on the atomic number of each element.

PERIODIC TABLE. An arrangement of the periodic system in the form of a table, which is the most common arrangement.

PERISPHERE. The volume surrounding an object in which the gravitational, magnetic, or electric fields of the object produce observable effects.

PERMALLOY. A series of high permeability nickel-iron magnetic alloys. In the United States the number prefix indicates the per cent nickel (i.e., 65 permalloy is 65% nickel).

PERMANENT EMPLACEMENT. In weapon system usage, a missile launching site with permanent features: e.g., antiaircraft sites to protect United States cities (Nike; ICBM

sites in Zone of Interior (Z.I.); coast protection; etc.).

PERMANENT SET. A measure of the inability of a material to return to its original dimensions after removal stress. It is normally determined after sufficient stress is applied to produce a 0.2% strain.

PERMANENT SITES. Guided missile sites used for launching very large missiles, usually from the continental United States (Zone of Interior (Z.I.)).

PERMATRON. A hot-cathode, gas-discharge diode in which the start of conduction is controlled by an external magnetic field.

PERMEABILITY (μ). (1) Absolute permeability, B/H , or **magnetic induction** divided by **magnetizing force**. (2) Specific (relative) permeability $\mu_r = B/\mu_v H$ (μ_v = permeability of vacuum). These meanings are distinct in the mksa system, but not in the usual cgs emu system, where μ_v is defined to be unity. (3) The capacity of a membrane or other material to allow another substance to penetrate or pass through it; or the quantity of a specified gas or other substance which passes through under specified conditions.

PERMEABILITY TUNING. The variation of the resonance frequency of the tuned circuits of a receiver or transmitter by changing the effective permeability of the inductor's core. The most general way in which this is done is by varying the position of a **ferrite** slug with respect to the coil. An alternate method, which is less used because of its deleterious effects on the **Q** of the coil, decreases the coil inductance by inserting a brass, copper or aluminum slug into the center of the coil.

PERMEAMETER. An **electromagnet** arranged for magnetizing a specimen, and allowing measurement of the flux through the specimen and the **magnetizing force** at the surface. Various types of permeameter have been designed, aiming at ease of operation, accuracy of results, or use with high-coercivity materials.

PERMEANCE. The susceptibility of a material to magnetic flow; the reciprocal of **reluctance**.

PERMITTIVITY OR DIELECTRIC CONSTANT. The Coulomb law for two charges immersed in a dielectric medium gives the mutual force as

$$F = \frac{q_1 q_2}{\epsilon r^2}.$$

The constant ϵ is the absolute permittivity of the medium, and the ratio $\epsilon/\epsilon_0 = K$ is the relative permittivity or dielectric constant. ϵ_0 is the **electric constant** or the permittivity of free space. (See **dielectric constant**.)

In rationalized systems of units (see **units**) the Coulomb law is written

$$F = \frac{q_1 q_2}{4\pi\epsilon_r r^2}$$

and the permittivity ϵ_r is less than in unrationalized systems by a factor of 4π .

PERSEIDS. The Perseids furnish the most reliable of all **meteor showers**. While the Leonids have provided some very brilliant displays in the past, about three times each century, their appearance in the intervening years is not at all striking. The Perseids make their appearance during August of each year. Because of the fact that the Perseid showers never are as striking as the Leonids, when at their maximum, we should not expect to find them referred to so frequently in the ancient writings. Extensive search has been made through the old records, however, and we find mention of the Perseids as far back as 830 A.D. The first determination of the **radiant point** in the constellation of **Perseus** was apparently made in 1834.

In appearance the members of the Perseid shower are as striking as those from any other radiant point. Coming as they do during the month of August, when the nights are warm, they are seen by large numbers of people who are always impressed by the relatively slow motion, distinctly reddish appearance, and trails, frequently of several seconds' duration, which characterize the members of this swarm.

PERSEUS. This is a rich and brilliant **constellation** of the northern sky. Since it lies right in the Milky way it presents many beautiful fields for the opera glass or the small telescope. This is particularly true of the bright star Alpha Persei, which lies in the midst of a very rich and beautiful field.

The star **Algol** (Beta Persei) is the famous

eclipsing variable whose striking changes in light intensity caused the Arabs to name it the demon star.

PERSHING. A U.S. Army Ordnance solid propellant rocket in the development stage. It is a replacement for **Redstone**. Major contractors are Thiokol, solid rocket motors; Eclipse-Pioneer Division of Bendix, inertial guidance; Bulova, fuzing and arming; and Thompson Products, transporter-erector-launcher. (See **missile, guided**.)

PERSONAL EQUATION. In making measurements of any character every observer, no matter how skilled he may be, is bound to make certain errors. These errors are of two kinds: accidental errors which will be small in the case of a good observer and which will be distributed in accordance with the laws of probability; and systematic errors or errors which are always in the same direction and of approximately the same magnitude. The value of the systematic error is known as the personal equation of the observer. Personal equation must be determined empirically for each observer under a variety of different observing conditions. For a good observer the personal equation remains remarkably constant over long periods of time and may be applied directly to any observation.

PERTURBATION MANEUVER. Maneuver.

PERTURBATION THEORY. The study of the effect of small changes on the behavior of a system. In the general treatment of a problem by the method of perturbations, a differential equation which neglects the small change is solved. The resulting solution is then substituted into a more exact differential equation and terms which are of second order or higher in the ratio of the change of the solution to the original solution are neglected. The resulting equation for the change, in terms of the causes of perturbation and the original solution, is often far simpler than the exact equation, including the perturbing effects, would have been.

PERTURBATIONS. (1) If there were only two bodies in the universe and if each of these were a homogeneous sphere, the orbit of one relative to the other, or the orbits of both relative to the common center of gravity of the system, could be completely determined

by the solution of the **two body problem**. In reality, however, there are many more than two bodies in the universe and few of them are homogeneous spheres, with the result that the determination of accurate orbits becomes a problem of tremendous complexity.

Within the **solar system** it fortunately happens that the attraction of one body is dominant, i.e., the attraction of the sun upon any object is far greater than the attractions of all of the other planets combined. In the cases of **satellites**, the attraction of the primary is preponderant. In such cases a close approximation to the true orbit may be obtained by neglecting the attractions of other objects and obtaining a preliminary orbit by the methods of solution of the two body problem.

The influences which the attractions of the other members of the solar system have on the motions of the object under consideration are known as perturbations. In the case of nearly circular orbits, as in the case of the motions of the planets about the sun, it is possible to obtain, in the form of infinite series, an analytic expression for the perturbations. Such a solution is known as general perturbations. If the orbit is highly eccentric, as in the case of many comet orbits, it is not possible to obtain any general analytic expression and the perturbations are known as special perturbations. (2) In space flight, the disturbance of an orbit by gravitational or other (e.g., drag) effects. Perturbations make the navigational problem exceedingly complex. They will also complicate the guidance-control problem, since the application of motor thrust to correct path errors must include consideration of the perturbation effects if the proper return to course is to be attained.

PERTURBATIVE FORCE. In space flight, the resultant of all forces causing a disturbance of the orbit.

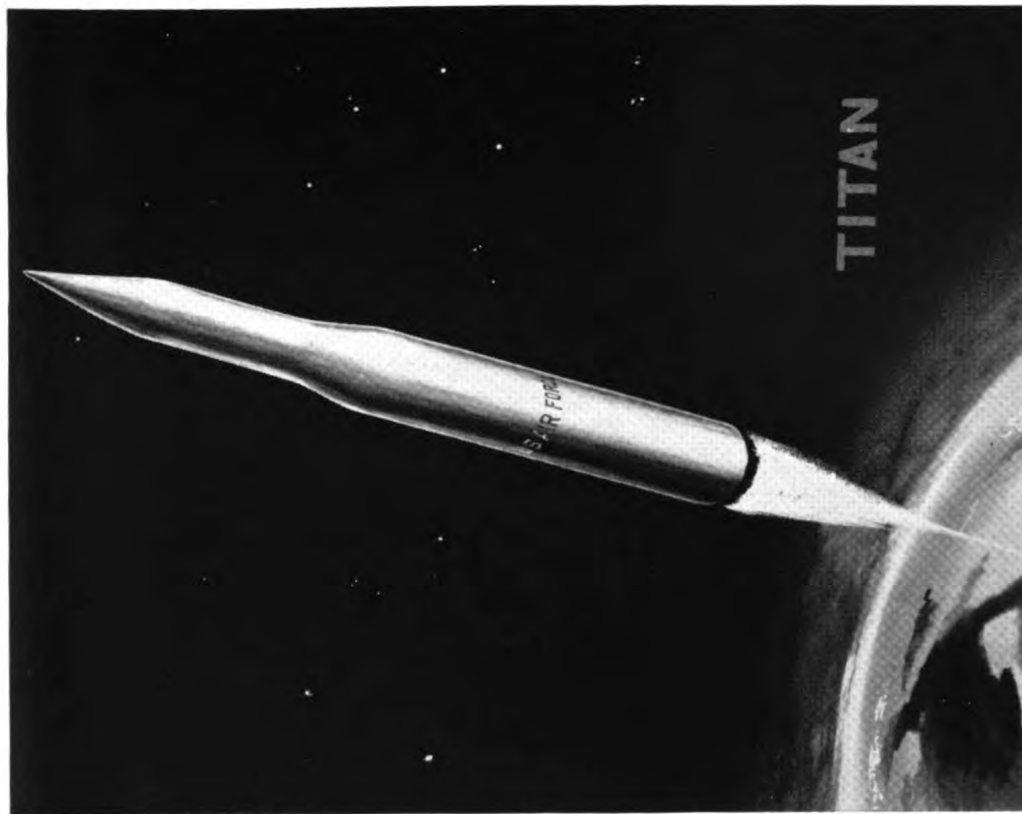
PERVEANCE. The quotient of the space-charge-limited cathode current by the $\frac{3}{2}$ -power of the anode voltage in a diode. Perveance is the constant G appearing in the Child-Langmuir-Schottky equation.

$$i_k = Ge_b^{\frac{3}{2}}.$$

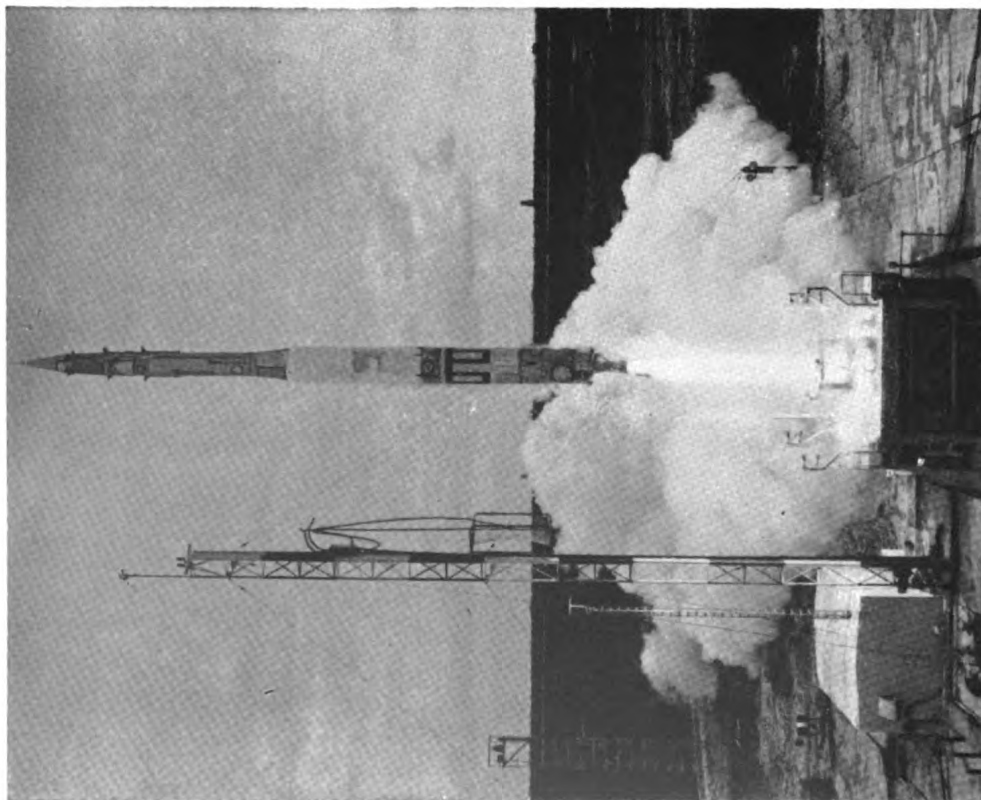
When the term perveance is applied to a triode or multi-grid tube, the anode voltage e_b is replaced by the composite controlling voltage e' of the equivalent diode.



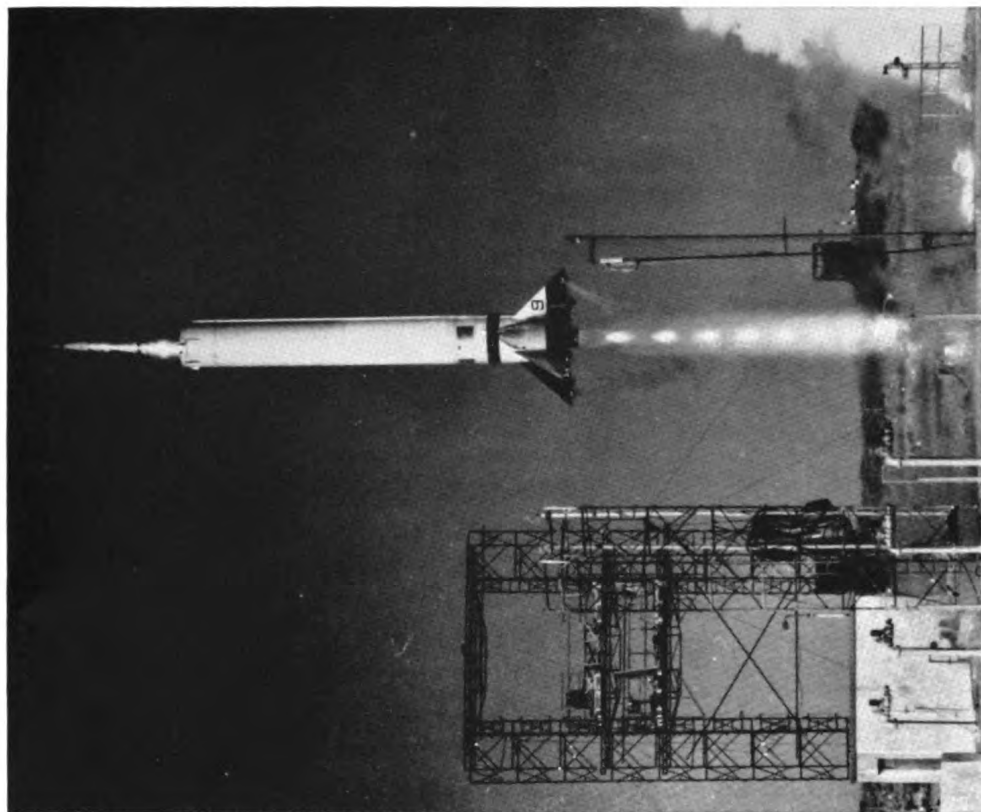
Firing of THOR ABLE I lunar probe on August 17, 1958 at Cape Canaveral, Florida. An explosion ensued 77 seconds after take-off. (U.S. Air Force Photograph)



This is an artist's conception of the Air Force TITAN Intercontinental Ballistic Missile under development by the Martin Company. (U.S. Air Force Photograph)



The third of the Navy's VANGUARD tests leaves its launching pad at the Air Force's Missile Test Center, Cape Canaveral, Florida, at 3:22 p.m. (EDT), on October 23, 1957. The test vehicle contained a prototype of the VANGUARD's first stage and "dummy" second and third stages weighted to simulate actual weight of the final earth satellite launching vehicle. (*U.S. Navy Photograph*)



U.S. Navy's Martin VIKING #9 high altitude research rocket starts on its way to equal the world's record for single-stage rocket of 135 miles. It is the ninth of ten to be built by Glen L. Martin Company for Naval Research Laboratory and was launched at White Sands Proving Ground, Las Cruces, New Mexico. (*U.S. Navy Photograph*)

PET. Production environmental testing.

PET. A miniature solid-propellant rocket motor made by the Atlantic Research Corporation. The name is derived from the words, *propulsion experimental test*. It delivers 40 lbs thrust for 1 second. It is 1.5 inches in diameter, 4.75 inches in length, and 0.6 lbs in weight. It uses 0.213 lbs of Arcite composite propellant. It is similar in type to the small retro and spin rockets used in the third stage of **Vanguard**.

PETAL CATCHERS. Devices used in shock tubes, pneumatic and hydraulic systems to capture burst diaphragm elements after rupture to avoid damage to the downstream system.

PETREL. A U.S. Navy air-to-surface missile produced by the Fairchild Guided Missile Division. It was built around the standard Mk 13 aerial torpedo. Fairchild used a turbojet engine for power. It was 24 feet in length, with a wing span of 13 feet. It was air-launched from patrol type aircraft. It used an active homing type of **guidance**. Its official designation was the AUM-N-2. It was developed under the Bureau of Ordnance. It was placed in war reserve in 1957, and production was suspended. (See **missile, guided**.) (See also illustration facing Page 314.)

PHANASTRON. A circuit used for producing a rectangular pulse of short duration.

PHANTASTRON. (1) A monostable multivibrator used to generate very short pulses and linear sweeps. (2) A certain type of one-tube relaxation oscillator employing Miller feedback to generate a linear timing waveform. This class of circuits has been called Sanatron and Sanaphant.

PHANTOM ACCELERATIONS. The accelerations which a missile in flight experiences (1) because the earth is not a perfect sphere, and (2) because of the Coriolis effect.

PHANTOM CONNECTION. A technique for connecting a number of wires, whereby the total number of available circuits is increased over the total number of wire-pairs by regrouping the wires to form additional (phantom) circuits. From two pairs of wires, two real circuits and two phantoms can be obtained. (See **simplixed circuit**.)

PHASE. (1) A time division of tasks in the programming of military development work. In U.S. Air Force Research and Development terminology, a phase is an activity within the R&D sphere of responsibility from the conception of the idea to the phase-out of the item in the Air Force inventory. The following phases are established: (a) Task initiation—from conception of idea to formal approval; (b) Study—investigation leading to an experimental proposal or a published finding; (c) Experimental—fabrication or assembly ending at evaluation of **bread-board**, mock-up or other prototype; (d) Developmental—fabrication, refinement, and evaluation of a model or technique ending at engineering inspection; (e) Operational suitability—evaluation of the item or technique under simulated field conditions ending at the time that it has completed operational suitability tests; (f) Preliminary production—engineering development ending with authorization for full scale production; (g) Production—production engineering ending with completion of production; (h) In-service—engineering development eliminating unsatisfactory conditions and ending with phase-out of Air Force inventory. (2) In general usage, a phase is one of two or more forms, appearances, or forms of behavior exhibited by the same entity, as the phase of the moon, of alternating electric current, of protoplasm, and of bacteria. (3) In mathematics, a phase is the argument of the harmonic function in the mathematical expression for the disturbance in a harmonic wave, as in $u = Ae^{i(\omega t - kx)}$, $\omega t - kx$ is the phase. In the harmonic oscillation, $x = Ae^{i(\omega t + B)}$, $\omega t + B$ is the phase, and B is the initial phase or epoch. (4) The phase of a periodic quantity, for a particular value of the independent variable, is the fractional part of a period through which the independent variable has advanced, measured from an arbitrary origin. In the case of a simple sinusoidal quantity, the origin is usually taken as the last previous passage through zero from the negative to positive direction. The origin is generally so chosen that the fraction is less than unity. The phase is expressed in radians, rather than in periods, in which use its numerical value is increased by a factor of 2π . (5) In the phase rule, used in physical chemistry, a phase is a homogeneous, physically-distinct part of a system which is separated from other parts

of a system by definite bounding surfaces. Thus a gas, a homogeneous liquid, or a homogeneous solid is a single phase, while, for example, a system of two insoluble or partly-soluble liquids which form separate layers has two phases, and a system of two solids in equilibrium with their solution has three phases. (6) In a related usage in electricity, one speaks of single-phase, double-phase, or most frequently, three-phase current. This refers to the wave components of current produced at a source and supplied to a load. (See **alternating currents**.)

PHASE ANGLE. A conventional representation of simple harmonic motion is

$$y = A \sin(\omega t + \alpha) = A \sin\left(\frac{2\pi t}{T} + \alpha\right)$$

in which A is the amplitude,

$$\omega t + \alpha \quad \text{or} \quad \frac{2\pi t}{T} + \alpha$$

is the phase angle, and α is the epoch angle, t is the time variable, T is the period and ω is the angular velocity.

Two coherent harmonic motions, described by

$$y_1 = A \sin(\omega t + \alpha)$$

and

$$y_2 = A \sin(\omega t + \beta)$$

are said to have a phase difference of $(\beta - \alpha)$.

PHASE CONSTANT. Of a traveling plane wave at a given frequency, the space rate of decrease of phase of a field component (or of the voltage or current) in the direction of propagation, in radians per unit length.

PHASE CONVERTER. If single-phase voltage is applied to one **phase** of a rotating three-phase induction **motor** it will be found that approximately balanced three-phase voltages may be obtained from the three terminals of the machine. This is because the rotating field induces voltages in the various phase windings which are not much different from the applied voltage. Since the single-phase field is not quite uniform and since the impedance drop in the windings affects the terminal voltage, the output voltages are not quite equal, but nearly enough so that they may be used for much three-phase work. This method is used quite widely in a-c rail-

way electrification since the necessity of three conductors makes transmission of three-phase power to the locomotive difficult.

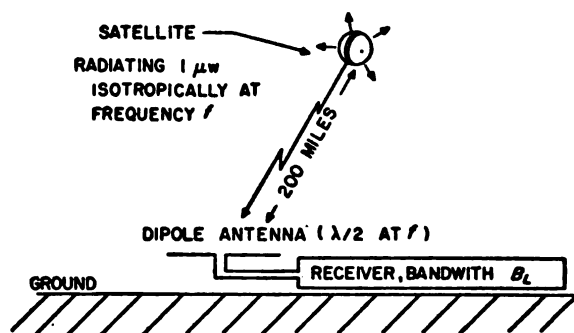
PHASE DIFFERENCE. Phase angle.

PHASE DISTORTION. Phase-frequency distortion.

PHASE-FREQUENCY DISTORTION. Distortion due to lack of direct proportionality of phase shift to frequency over the frequency range required for transmission. Delay distortion is a special case. This definition includes the case of a linear phase-frequency relation with the zero frequency intercept differing from an integral multiple of π .

PHASE INVERTER. A device for reversing the polarity of a signal. A **transformer** can be used as a phase inverter, as can a **paraphase amplifier**, or any resistance-capacitance coupled amplifier.

PHASE-LOCK DETECTION. One method of **correlation detection** in practical receiving systems is the phase-locked loop which is particularly applicable when the transmitted signal is a pure sine wave. In the phase-locked loop (see figure) the local



Phase-lock detector.

estimate of the transmitted signal is generated by a voltage controlled oscillator (VCO), and the mathematical operation of multiplication is performed by the phase detector. This phase detector provides a d-c output voltage which is proportional to the phase difference between the incoming signal and the local estimate generated by the VCO. The d-c error voltage is separated from noise by the low-pass filter (integrator) to provide a control voltage to the VCO. In this way the phase-locked loop is an electronic servomechanism

which accomplishes signal detection using only linear mixing. This system provides memory by virtue of the voltage stored on the integrating capacitor in the low-pass filter. This voltage is always a "best guess" of the present signal frequency and is retained for some time after disappearance of the signal, thus providing a means for reacquiring the signal should it appear again at the same frequency. The design of a phase-locked loop for a particular application requires detailed knowledge of target dynamics and their effect on signal characteristics.

The simple phase-locked loop shown is a servo system which locks a VCO in phase synchronism with a sine wave signal input, in spite of a large amount of noise that may also be present at the input. If the system is assumed to be initially in lock (i.e., if the VCO has exactly the same frequency as the input signal), the output of the phase detector will be directly proportional to the cosine of the phase difference between the signal and the VCO output. This phase detector output, when filtered by the low-pass filter, is a control voltage which will maintain phase synchronism with the VCO output 90 degrees from the input signal. The low-pass filter effectively removes the noise from the control voltage so that VCO output is very clear and is a good measure of signal frequency and phase. In a second channel, the signal is shifted in phase by 90 degrees so that it is in phase with the VCO output. The phase detector in this channel then produces a d-c voltage which is proportional to the signal amplitude. In this manner, the signal is completely detected by the phase-locked loop; i.e., the frequency, phase and amplitude are determined.

This description of the phase-locked loop assumes that the loop is initially locked. Initial acquisition of the signal may be accomplished by slowly sweeping the VCO frequency across the signal frequency. As the beat between the signal and the VCO output goes to zero, the system acquires phase-lock and thereafter retains synchronism, unless the signal level becomes so small that the available control voltage can no longer overcome the effects of the small amount of noise which appears at the output of the low-pass filter.

PHASE MARGIN. A stability criterion for feedback systems equal to 180° minus the

total phase-angle encountered in the feedback loop at the frequency where the loop gain is unity.

PHASE MODULATION. Modulation, phase.

PHASE PLANE (METHOD). A technique for analyzing servo performance. The response of a servo is plotted as a function of velocity vs. displacement (instead of displacement vs. time), for a variety of step amplitudes to provide a phase portrait in the phase plane. Note that phase does not relate to phase angle or phase shift associated with linear servo frequency.

Stability of the servo is determined from the phase portrait.

PHASE SHIFT. A time difference between the input and output signal of a control unit or system.

PHASE SPLITTING CIRCUIT. A circuit that produces from the same input waveform two output waveforms that differ in phase from each other.

PHASE, TERMINAL. Terminal phase.

PHASE VELOCITY. Waveguide, modes of operation; antenna, slot.

PHASING, SYSTEM. System phasing.

PHASITRON. A frequency-modulator tube designed to make possible the introduction of comparatively-wide phase excursions at audio rates in a crystal-controlled, radio-frequency carrier voltage.

PHOBOS. One of the satellites of Mars.

PHON. The unit of loudness level of a sound, defined as the sound pressure level equal to the sound level in decibels relative to 0.0002 microbar of a simple tone of frequency 1000 cycles per second which is judged by the listeners to be equivalent in loudness.

PHONON. A progressive wave in an acoustic mode of thermal vibration of a crystal lattice (or in liquid helium II). The theory of lattice vibrations is in many respects similar to that of the electromagnetic field, and it is convenient to introduce "particles," defined by wave-packets, moving through the

medium with the group velocity, and capable of being annihilated, created, scattered, etc., by interaction with electrons and lattice imperfections. Like a photon, a phonon is quantized to have the energy $h\nu$, where ν is its vibrational frequency, and h is Planck's constant. The concept of phonons allows a great formal simplification in theories of thermal and electrical conduction in solids.

PHOSPHOR. A substance which exhibits **luminescence**. Phosphors are used in the screens of **cathode ray tubes** and in many other applications to intensify radiations in the visible range, or to transform nonvisible frequencies into visible ones.

PHOSPHORESCENCE. The property of emitting light following excitation by light, or by other electromagnetic or particulate radiations.

PHOSPHORUS. Non-metallic element. Symbol P. Atomic number 15.

PHOT. A unit of **luminance** equal to 1 lumen/sq cm.

PHOTOCATHODE. An electrode used for obtaining photoelectric emission when irradiated, which is thus the irradiated negative electrode in a **phototube**. (See also **photoemissive effect**.)

PHOTOCELL. The old designation for all photoelectric devices, including those discussed in this book in the entries on **photoconductive detector**, **phototube** and **photo-voltaic cell**.

PHOTOCONDUCTIVE DETECTOR. Apparatus used to detect (and/or measure) **radiant energy** by change in electrical resistance. Semiconductors such as lead sulfide, lead selenide, lead telluride, germanium and many others, when doped with the proper amount of certain impurities, are used as radiation detectors, particularly in the near (1-10 microns) infrared because of their photoconductive properties.

PHOTOCONDUCTIVE EFFECT. Many substances exhibit a marked increase in electric conductivity when illuminated. Thus gases may be ionized by light as well as by ultra-violet radiation or x-rays. But the term photoconductivity is commonly applied to

crystals which, ordinarily very poor conductors, become distinctly conducting under the action of light. In general terms, the light excites electrons into the conduction band, where they can move freely, and carry a current.

The most noted example of this phenomenon is found in selenium, whose photoconductivity has been known since its discovery in 1873 by May. Unfortunately selenium is far from typical in its manifestations of the property, and the hundreds of researches on it have given many conflicting data. It has finally been recognized, from the work of Gudden and Pohl, that photoconduction is of two general types: primary or true photoconduction, which is the direct result of radiation penetrating the substance; and secondary effects set up by the photoconduction itself. The fact that in selenium the several secondary effects quite obscure the primary photoconduction is what has occasioned so much confusion. The primary photoconduction current in a crystal is in general proportional to the intensity of the illumination; the secondary is not, and, in the case of "light-negative" selenium, it may actually neutralize the primary and render the crystal less conductive than when in the dark. Some crystals, said to be "idiochromatic," are photoconductive in the pure state, while others, called "allochromatic," acquire the property only by reason of impurities or of previous exposure to suitable radiation. Other representative photoconductive substances are lead sulfide and germanium.

PHOTOELASTICITY. This badly chosen term refers to certain changes in the optical properties of isotropic, transparent dielectrics when subjected to stresses. For example, a block of glass, free from optical flaws, exhibits "forced" **double refraction** when put under compression or tension parallel to one of its dimensions. If the block is placed between crossed Nicol prisms, the field remains dark so long as the glass is in its normal condition, but as stress is applied, colored fringes appear which are characteristic of the internal deformations of the glass.

PHOTOELECTRIC EFFECT. In its earlier use, this term covered broadly all changes in electrical characteristics of substances due to radiation, generally in the form of light. Currently, the **photoconductive effect** and the

photovoltaic effect, in their narrower meanings, are not included, and they are defined separately in this book, and the term photoelectric effect is restricted to the "photoemissive effect." In this effect, radiation of sufficiently high frequency, "short wavelength," impinging on certain substances, particularly, but not exclusively, metals, causes bound electrons to be given off with a maximum velocity proportional to the frequency of the radiation, i.e., to the entire energy of the **photon**. The Einstein photoelectric law, verified first by Millikan, states

$$E_k = h\nu - \omega$$

where E_k is the maximum kinetic energy of an emitted electron, h is the **Planck constant**, ν is the frequency of the radiation (frequency associated with the absorbed photon), and ω is the energy necessary to remove the electron from the system.

PHOTOELECTRON-MULTIPLIER TUBE. **Electron-multiplier phototube.**

PHOTOFISSION. Fission, nuclear.

PHOTOGRAMMETRY. The process of determining spatial locations of objects by means of their relative positions on two or more photographs taken from different points. In missile proving ground instrumentation, the missile trajectory data are obtained by the use of either fixed or tracking cameras situated at the ends of an accurately-measured base line. The missile trajectory is reconstructed mathematically by methods of triangulation. The triangulation operation may be performed by intersection (i.e., ordinary surveying computations), or by stereo-photogrammetry (i.e., three-dimensional analysis). The ideal photogrammetric camera has distortion-free characteristics, an optically-flat image plane and complete absence of emulsion shrinkage. The position of the missile in flight is calculated by use of the azimuth and elevation angles of the cameras, which may be photographed on each frame of film from small internal dials (the principle of the **phototheodolite**) and read from the film by means of microscopic comparators or enlarged image readers. The comparator measures the deviation of the missile from a central reference on the particular frame, and adds or subtracts from the internal dial readings (after converting the deviation to an equivalent azimuth and

elevation angle). Two cameras' data are adjusted for exact time correlation and the angular values of position are introduced into computers, along with corrections for all known errors (e.g., curvature of the earth, instrument and recording errors, synchronization errors, angular lens distortion, etc.). The computer gives position, velocity and acceleration from these time-fixed angles. In general two or more cameras are necessary to determine the location of an object in space, since each can define only a single line. In practice, often four or more cameras are used to reduce errors. (See also **data reduction**, **least squares method**, **phototheodolite** and **ballistic camera**.)

PHOTOGRAPHY. In support of missile research and development, the following photographic activities are conducted: (1) Administrative (including reproduction, blue print, photostat, etc.); (2) Technical (including metric data); and (3) Documentary (motion pictures or stills showing the project progress for historical or orientation purposes). With respect to a particular missile project, photographic services are classed as either: (1) Metric—or data collection; (2) Documentary—preparation of the missile, ground operations, launching and other historical activities; (3) Engineering Surveillance—photography accomplished with or without time reference, to show the development or deployment of technical events associated with the project. A restricted subclassification under engineering surveillance is engineering sequential, which is time-correlated photography not intended for metric purposes, but to show qualitative information concerning a particular event.

PHOTOMETER. An instrument used to measure luminous intensity, luminous flux density, or illumination.

PHOTOMULTIPLIER. An **electron multiplier tube** so constructed that the secondary emission is directed on a cascade of **photoelectric cells** to produce **current amplification**. Photoelectrons emitted from the cathode of a photoemissive cell are accelerated, and focused on a second electrode called the collector or target, where each of the original ("primary") electrons may produce several secondary electrons upon impact. Multiple staging of this process yields very great gains.

The electron multiplier photocell gives an output on the order of several milliamperes from a very weak light source, such as that of a fifth magnitude star.

PHOTON. (1) A quantum of **electromagnetic energy**. The energy of a photon is $h\nu$, where h is Planck constant, and ν is the frequency associated with the photon. The term photon usually refers to a plane-wave quantum of electromagnetic energy, for which the momentum is $h\nu/c$, and the component of angular momentum in the direction of the momentum is $\pm\hbar$ where c is the velocity of light and \hbar is $h/2\pi$. (2) A name once given to the unit of visual stimulation now called the troland.

PHOTON ENGINE. A projected type of reaction engine in which thrust is to be obtained from a stream of **photons**.

PHOTORECORDER. A photographic device for recording the readings of instruments, especially of flight-test instruments or of instruments sent to high altitudes in rockets.

PHOTOSPHERE. The intensely bright portion of the sun which is visible to the unaided eye is known as the photosphere. In reality it is a layer not more than a few hundred miles in thickness which marks the boundary between the dense interior gases of the sun and the cooler, more attenuated gases which go to make up the solar atmosphere. The photosphere radiates with a continuous spectrum and the application of the laws of radiation indicates that its temperature is about 5750°K .

In appearance the photosphere is brilliantly white, somewhat brighter at the center than at the limb, and is distinctly granular in character. These granules are in reality very large, as much as several hundred miles in diameter, and are relatively short-lived, photographs taken at intervals of less than a minute showing distinct changes. Larger irregular bright areas known as faculae may be frequently seen. Spectroscopic analysis of the light from the faculae indicates that they are masses of heated gases which are rising out through the photosphere to the atmosphere.

Spectroheliographic studies of the photosphere show the presence of areas of hydrogen and calcium vapor, known as flocculi which

are somewhat smaller than the faculae and larger than the "granules."

PHOTOTHEODOLITE. An optical tracking instrument used to film the flight of a missile, recording it in angular coordinates against time. Essentially it is a telephoto motion picture camera arranged to permit smooth tracking of the missile in flight, and to record the sighting angles to it. One of the more advanced instruments of this type is the Askania phototheodolite, produced by the German company of that name. Phototheodolite range is extended in four ways: (1) by improving the visibility of the target by increasing its contrast with the background; (2) by improving the tracking telescope; (3) by increasing the focal length of the phototheodolite; and (4) by using phototheodolites in a chain-type of instrumentation, where a series of them, all tied to the same timing, track the missile throughout the range of each instrument. The stations along the anticipated trajectory take over successively, with sufficient overlap to provide an uninterrupted record.

PHOTOTUBE. An **electron tube** that contains a **photocathode**, and has an output depending at every instant on the total **photoelectric emission** from the irradiated area of the photocathode.

PHOTOVOLTAIC CELL. (1) Apparatus used to detect (and/or measure) **radiant energy** by generating a potential in the boundary (called the barrier layer) of an electrode consisting of two types of material, by the action of the radiant energy to be detected. (2) An electrolytic cell which sets up an electromotive force upon incidence of radiation, commonly light.

PHOTOVOLTAIC EFFECT. The production of an electromotive force by incidence of radiant energy, commonly light, upon the junction of two dissimilar materials, such as a p - n junction or metal-semiconductor junction.

PHUGOID. In aerodynamics, a term meaning of or pertaining to the longitudinal motion of the vehicle. Thus, phugoid oscillations are variations in the longitudinal motion of a vehicle. A vehicle undergoing such oscillations acts as if it were hunting its proper

course, and describes pitching and/or yawing oscillations of very long period.

P-I. Photogrammetric instrumentation.

PI MODE. Mode, PI.

PICKOFF. (1) A device for converting mechanical motion into an electric signal proportional to the mechanical motion. (2) A sensing device, used in combination with a gyroscope in an automatic pilot or other automatic apparatus, that responds to angular movement to create a signal or to effect some sort of control. A pick-off may be a potentiometer, a photoelectric device, a kind of valve controlling the fluid flows and pressures in a system, or one of various other devices.

PICKUP. A common expression for a transducer or end instrument.

PIERCE CRYSTAL OSCILLATOR. An oscillator in which a piezoelectric crystal is connected between the plate and the grid of a tube, which is basically a Colpitts oscillator. It has a low output, but has frequency stability and requires no tuning.

PIEZOELECTRIC EFFECT. The interaction between electrical and mechanical stress-strain variables in a medium. Thus, compression of a crystal of quartz or Rochelle salt generates an electrostatic voltage across it, and conversely, application of an electric field may cause the crystal to expand or contract in certain directions. Piezoelectricity is only possible in crystal classes which do not possess a center of symmetry. Unlike electrostriction, the effect is linear in the field strength.

The directions in which tension or compression develop polarization parallel to the strain are called the piezoelectric axes of the crystal.

The magnitude of the piezoelectric polarization is proportional to the strain and to the corresponding stress, and its direction is reversed when the strain changes from compression to tension. The principal piezoelectric constants of a crystal are the polarizations per unit stress along the piezoelectric axes. While these constants are much greater for Rochelle salt than for quartz, the latter is better adapted to some purposes because of its greater mechanical strength and its stability at temperatures over 100°C.

PIGTAIL. (1) A short, coiled connecting wire, or a short bundle of connecting wires, such as an igniter connector for rockets. (2) A short, flexible connecting wire between two parts having slight relative motion.

PI-INSTRUMENTATION. A system of photogrammetric instrumentation, in use at White Sands Proving Ground, New Mexico. The system provides a method for the determination of trajectories of missiles by means of two precision-plate camera theodolites. These cameras, set upon an accurately measured base line, are calibrated and oriented by means of photographed star trails or terrestrial reference markers. The camera shutters are synchronized to an accuracy of 200 microseconds, and are coded by means of an auxiliary capping shutter. The system uses German Askania cameras which were designed for synchronized use on a much shorter base line. The PI system allows the cameras to be extended to a distance of 100 miles, with only four pairs of wires between them. The two cameras are synchronized from a centrally-located control center halfway between the two. The method of synchronization is based upon the adjustment of one shutter motor to coincidence with that of the other station. The appearance of shutter returns is monitored on an oscillograph, and the second station's camera motor power increased or decreased until synchronization occurs.

PILE. A nuclear reactor. The term pile comes from the first nuclear reactor, which was made by piling up graphite blocks and pieces of uranium and uranium oxide. The term reactor is current.

PILOT. A U.S. Navy plan for aircraft launch of a three pound payload satellite, using an F8U firing a solid propellant multistage vehicle from an altitude of 80,000 feet.

PILOTLESS AIRCRAFT. An aircraft which is equipped to function without a human pilot aboard. An obsolescent term for a guided missile. The term is sometimes used to describe a drone.

PILOTLESS BOMBER. Specifically, a winged guided missile without a human pilot, designed to be launched against surface targets.

PILOTLESS MISSILE. A popular term for a guided missile or ballistic missile. Since missiles are normally "pilotless," this term is tautological unless used in context where distinction is being made between an ordinary guided missile and a vehicle in which the pilot serves only a limited function, as final landing control.

PINCH EFFECT. The constriction of an electrically conducting medium, such as an ionized gas or plasma, in a magnetic field. (See **magnetohydrodynamics**.)

PING. A pulse of sound of finite duration sent out by a **transducer**.

PINGER. A mechanical sounding device sometimes carried aboard missiles flying over water as an aid to location and recovery of the missile from the water after impact. The pinger emits a continuous acoustic signal which can be located by shipboard sound equipment. The range of such instruments is dependent upon size, but a small one weighing 10-15 pounds would be audible at an underwater distance of a half mile or so, and would be capable of operating for a period of about 10-14 days on its internal power supply. Pingers are normally used with aerodynamic type missiles. (See also **beeper**.)

PINPOINT. A type of automatic guidance developed by the Goodyear Aircraft Corporation under a U.S. Air Force contract and reportedly combining map matching and inertial guidance principles.

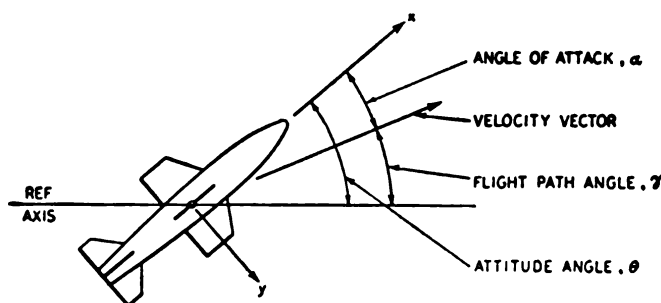
PIONEER. The name of a series of lunar probes. (See also **instrumental vehicles for space research**, and **Thor-Able**.) Pioneer I was fired at Cape Canaveral, October 11, 1958. The 83-pound payload failed to attain escape velocity and was destroyed by re-entry

into the earth's atmosphere after attaining an altitude of 79.212 miles. The flight nevertheless yielded valuable data on radiation and magnetic fields, as well as micrometeorite density.

PIP. In radar, a light spot, streak, line or other indication of the cathode ray oscilloscope. A pip usually indicates an echo return from a target or other object. It is synonymous with blip.

PISCES. (The fishes). A large constellation which is of importance principally because it is the twelfth sign of the **zodiac**. There are relatively few interesting objects in the constellation although the brightest star (Alpha) is a close double which may be resolved in instruments larger than a four-inch telescope. Even though Pisces is the twelfth sign of the zodiac, nevertheless, the **vernal equinox** is located in this constellation at present. This is because **precession** has caused the vernal equinox itself to move back an entire "sign" along the ecliptic since the time when the names were first assigned.

PITCH. (1) In aerodynamics, the movement of an airframe or missile about its center of gravity so that the nose turns in the plane defined by the center of gravity, the nose, and the center of the stabilized point used as the basic guidance reference (normally the center of the earth). For a ballistic missile, the *angle of pitch* is defined as the vertical component of the angle between the longitudinal axis of the missile and the instantaneous tangent of the trajectory. Intuitively, one can sense pitch as the vertical (i.e., "up" and "down"), deviation of the long axis of the missile from the ideal trajectory path. (See figure.) (2) In acoustics and sonics, pitch is the frequency of a sound. Actually this is



Pitch angle relationships.

true in sonics only. In acoustics, a more subjective definition is: "pitch is the attribute of auditory sensation which allows sounds to be arranged in order on a scale extending from 'low' to 'high' by a listener." Pitch depends upon the frequency, sound pressure, and waveform of the sound.

PITCH ATTITUDE. The attitude of an aircraft, rocket missile, etc., referred to the relationship between the longitudinal body axis and a chosen reference line or plane as seen from the side.

PITCH AXIS. A lateral axis through an aircraft, missile, or similar body, about which the body pitches. It may be a body, wind, or stability axis.

PITCH OF SCREW. Axial distance between adjacent turns of a single thread on a screw.

PITCH PROGRAMMER. A device used to provide initial pitch or tilt-over guidance to a vertically launched missile to put it "on target." The device may be airborne or ground-based with a radio link.

PITOT PRESSURE. In aerodynamics, ram pressure or pressure caused by impact of air against a surface.

PITOT TUBE. In aerodynamics, a fluid-filled pressure sensitive tube (manometer) arranged to measure wind impact pressure. The sensitive element of the tube is an open end pointed directly into the flow. (See also **pressure** and **velocity pressure**.)

PITOT-STATIC TUBE. An aerodynamic pressure-measuring device combining the pitot and static pressure tube responses. The ratio of the impact pressure to the static pressure is a function of the velocity of flow past the tube, and can be calibrated to measure that velocity (air speed). The pitot tube registers the dynamic pressure of moving air; the static tube measures the pressure of still air. Turbulence and local angle of attack affect the accuracy of the pitot-static tube, which is therefore frequently mounted on a probe which extends well forward of interfering surfaces.

PLAN FORM. The contour outline of an airfoil surface as seen from above. The "developed plan form," is the one-dimensional development of the surface as if it were pressed

down onto a horizontal plane with all gull-winging and dihedral removed. The projected plan form is the outline it would produce in silhouette.

PLAN POSITION INDICATOR (PPI). A radar display in which targets are positioned in terms of azimuth and distance.

PLANCK CONSTANT. Planck law.

PLANCK LAW. The fundamental law of the quantum theory, expressing the essential concept that energy transfers associated with radiation such as light or x-rays are made up of definite quanta or increments of energy proportional to the frequency of the corresponding radiation. This proportionality is usually expressed by the quantum formula $E = h\nu$, in which E is the value of the quantum in units of energy and ν is the frequency of the radiation.

h , the constant of proportionality, is known as the elementary quantum of action or more commonly, as Planck's constant. Since E is energy and ν is frequency, h has the dimensions of energy \times time, or **action**.

PLANE OF POLARIZATION OF A RADIO WAVE. The orientation of energy in an **electromagnetic wave** of radio frequency: determined by convention to be the direction of the **electric field** with respect to the earth's surface.

PLANE OF SYMMETRY. A vertical plane containing the longitudinal axis of a symmetrical object, as that of an aircraft or missile, on either side of which both parts of the object are symmetrical.

PLANET(S) OF THE SOLAR SYSTEM. There are nine principal planets now known in our solar system. All of these rotate about the sun as the center. They are **Mercury**, **Venus**, **Earth**, **Mars**, **Jupiter**, **Saturn**, **Uranus**, **Neptune** and **Pluto** (in order of distance from the sun). Statistics on these planets are tabulated on Page 452.

PLANETARY MOTIONS. The apparent motions of the **planets** on the **celestial sphere** have been observed, recorded and speculated about ever since mankind has existed on the earth. A large part of the pseudo-science of **astrology** is concerned with these motions, or, more particularly, with the various "as-

PLANETS OF THE SOLAR SYSTEM

Planet	Radius (cm) $\times 10^8$	Mean Distance to Sun $M_i \times 10^8$	Length of Year (Yr)	Orbital Velocity (Mi/Sec)	Escape Velocity (Mi/Sec)	Gravity at Surface (Earth = 1)	Period of Rotation	Mass (Earth = 1)	D_p/D_i^*	Albedo	Atmosphere
Mercury	2.4	36.0	88/365	29.7	2.2	0.27	88 days	0.04	1.3	7	None
Venus	6.1	67.2	224.7/365	21.7	6.3	0.85	UNK	0.8	1.2	59	CO ₂ + ?
Earth	6.38	93.0	365.25/365	18.5	7.0	1.0	1 day	1.0	1.1	50 ?	N ₂ + O ₂
Mars	3.4	141.5	1.88	15.0	3.1	0.38	24h 37m	0.11	1.3	15	CO ₂ + ?
Jupiter	71.4	483.3	11.86	8.1	37.0	2.64	9h 55m	317.0	1.8	44	CH ₄ + NH ₃
Saturn	60.4	886.1	29.46	6.0	22.0	1.17	10h 14m	95.0	2.1	42	CH ₄
Uranus	24.9	1,782.8	84.02	4.2	13.0	.92	10h 40m	14.7	1.9	45	CH ₄
Neptune	26.6	2,793.5	164.79	3.4	14.0	1.12	15h 40m	17.2	1.7	52	CH ₄
Pluto	?	3,675.0	248.43	2.7 ?	6.5 ?	0.9 ?	UNK	0.7	1.	6 ?	?

* D_p/D_i = Ratio of diameter of planet to diameter of iron sphere of same weight.

pects," or configurations, of the planets. The motions as seen from the earth are complicated by the fact that the earth is moving about the sun in the same direction as the planets, but with a different rate.

Apparent Motions Relative to the Sun. In Fig. 1, we have S representing the sun, E rep-

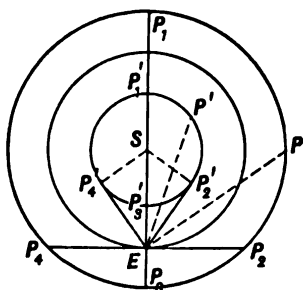


Fig. 1. Motions of planets as seen from earth relative to the sun.

representing the earth (assumed fixed for the purpose of convenience), P_1, P', P_2, P_3, P_4 indicating various positions of a planet whose orbit lies between the earth and the sun (inferior planet), and P_1, P, P_2, P_3, P_4 , positions of a planet whose orbit is outside of that of the earth (superior planet). The angle between the sun and the planet (e.g., SEP' or SEP) is defined as the elongation of the planet. For an inferior planet the elongation may have any value from 0 to SEP_2 or SEP_4 while for a superior planet the elongation varies either east or west from 0 to 180° . With elongation 0 we have the planet in the aspect of conjunction.

Inferior planets: It will be noted that the elongation is 0 both at P'_1 and also at P'_3 and hence there are two conjunctions for an inferior planet. To distinguish between them P'_1 is known as superior conjunction and P'_3 , inferior conjunction. An inferior planet moves more rapidly in its orbit than does the earth and accordingly from superior conjunction the planet moves out with increasing eastern elongation (evening object) to the point P'_2 (greatest eastern elongation). It then moves in with decreasing elongation, passes the sun and becomes a morning object at inferior conjunction (P'_3) and moves out with increasing elongation to P'_4 (greatest western elongation) and thence back to superior conjunction again. Hence these planets apparently oscillate back and forth across the direction of the sun. They do not ordinarily pass

either between the earth and the sun or directly behind the sun because of the fact that their orbits are not in the plane of the ecliptic (see *Transit of Venus*).

Superior Planets: It must be remembered that these planets are moving more slowly in their orbits than is the earth. These planets apparently move from conjunction at P_1 slowly out to the west of the sun (morning objects) to P_2 where the western elongation is 90° and the aspect is western quadrature. From this point the increase in western elongation increases rapidly to 180° at P_3 (aspect opposition) from which point the elongation becomes east (evening object) and decreases rapidly to 90° eastern elongation at P_4 (eastern quadrature). The decrease in eastern elongation then slows down as the planet moves slowly back to conjunction again.

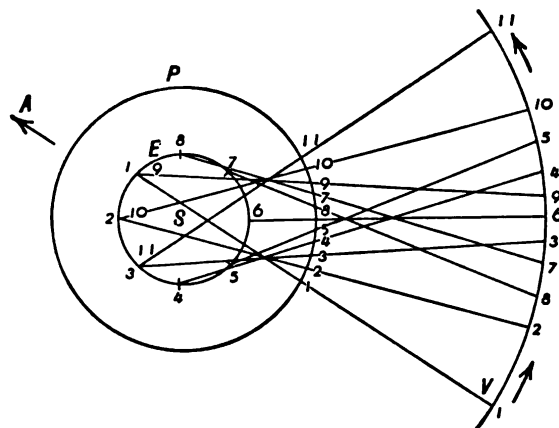


Fig. 2. Motion of planet as seen from the earth relative to the stars.

Apparent Motions of the Planets Relative to the Stars. In Fig. 2, we have S representing the position of the sun, E representing the (assumed circular) orbit of the earth, with successive positions marked, P the orbit of a planet with successive positions marked with numbers corresponding in date with the marked positions for the earth, and an outer circle representing directions on the celestial sphere, V being the direction of the vernal equinox, A the direction of the autumnal equinox and the direction of increasing longitude (or right ascension) indicated by arrows.

The successive positions of the planet as seen from the earth relative to the stars, are obtained by drawing lines, representing the lines of sight from successive positions of the earth through corresponding positions of the

planet. By examining the successive directions, as indicated by numbers on the outer circle, it will be evident that the general trend of the planetary motion is in the direction of increasing right ascension. Such motion in increasing right ascension is known as direct motion. It will be noticed, however, that in the vicinity of opposition of the planet, the motion reverses for a period (numbers 6, 7, and 8) and the planet moves in the direction of decreasing right ascension. Such motion, in the direction of decreasing right ascension, is known as retrograde motion.

Since the diagram is plotted in the plane of the ecliptic with the planet also assumed in this plane, the reversal in direction appears only in longitude. However, there will also be changes in direction of motion both in celestial **latitude** and **declination**, giving the appearance on the celestial sphere of loops in the motion of the planet.

PLANETARY ORBIT THEORY. The motions of the planets are described, to a high degree of accuracy, by the laws of Kepler. The consistency of these laws with the inverse square law (cf. **gravitation, Newton law of universal**) is the major basis of support of the latter. In accordance with the discussion given under **Coriolis effects**, the differential equations of motion are

$$m \frac{d^2 r}{dt^2} = -\frac{GmM}{r^2} + mr \left(\frac{d\theta}{dt} \right)^2,$$

$$mr^2 \frac{d^2 \theta}{dt^2} = -2mr \frac{dr}{dt} \frac{d\theta}{dt}$$

where G is the gravitation constant, m is the reduced mass of the planet, M is the mass of the sun, r and θ are the polar coordinates of the planet with the sun as origin. A single integration of the second equation yields the second law of Kepler. The substitution of $r^2(d\theta/dt) = C$ (a constant) into the first equation and an elimination of the time shows that the orbits are conic sections, being ellipses if the total energy is less than zero, hyperbolae if it is greater than zero and parabolae in the intermediate case. Reinsertion of the time leads to Kepler's third law.

All of the above treatment assumes that no bodies other than the sun affect the planet. No exact solution of the problem is possible when the effects of neighboring planets, satellites, etc., are taken into account, but per-

turbation theory may be used to obtain very close approximations. The agreement of theory and experiment has been excellent except in the case of Mercury, whose orbit is not quite that predicted. The fact that this exceptional case agrees with the prediction of the general theory of relativity, indicates that this theory offers a better approach than does the Newton law of gravitation, although the two theories agree within the observational accuracy for all of the other planets.

PLANETARY PROBES. Instrumental comets designed to explore the interplanetary spaces. They will usually be designed to approach quite closely to specified planets, and are thus designated as Venusian probes, Martian probes, etc. Planetary probes require comparatively less energy than some **solar probes**, but have longer transfer times. The atmospheres of Venus and Mars are still incompletely known. Close passages will reveal important new information on atmospheric composition and, for Mars at least, on surface features. If one stays within the earth-moon system, one can never get closer to Mars than about 35 million miles. Employing the greatest magnification available to the large telescopes on earth, Mars still appears only as large as the moon to the naked eye. Under these conditions an instrumental comet equipped with a wide-angle telescope of modest magnifying power and passing some 30 to 50,000 miles from the planet's surface will be certain to show a wealth of new details on the Martian surface, and correspondingly, in the structure of the atmosphere of Venus. Another interesting possibility would be to explore more deeply into the Venus' atmosphere by means of radar, measuring the attenuation spectra of various radar frequencies through uncondensed as well as condensed gases. Radar mapping Venus would, for the first time, yield information in regard to its surface features. However, for this purpose the comet must approach Venus quite closely, i.e., about 60 to 100 miles from the surface. A marked perturbation of the comet's path would result from a passage near Venus. This perturbation could be used for determining more accurately the mass of Venus, presently not sufficiently well known, because of the absence of a natural satellite.

PLANETARY SPACE. Space, planetary.

PLANETOID. A small planet, which is also called an **asteroid**. Between Mars and Jupiter there is an accumulation of many thousands of planetoids and asteroids in what is known as the "asteroid belt." These are masses of rock and metal, ranging in size from that of small stones to 480 miles in diameter (Ceres). More than 1500 fair-sized asteroids and planetoids have been recorded.

PLANETOLOGY. The study of planets and satellites, esp. in regard to the interpretation of their surface markings.

PLASMA. A partially ionized jet, a mixture of gas and electrically charged particles (e.g., ions, electrons) at high temperatures. These conditions obtain, in varying degree, in rocket thermodynamics and hypersonic aerodynamics. Plasmas are under investigation in the study of controlled **fusion nuclear reactions**. (See also **pinch effect**.)

PLASMA JET. A reaction propulsion scheme based upon the ejection of ultra-hot ionized gases through convergent-divergent nozzles, by using the **pinch effect** to avoid the (destructive) action of the hot gases on the nozzles.

PLASMATRON. A continuously-controllable **gas-discharge tube** which utilizes an independently-generated gas-discharge **plasma** as a conductor between a hot cathode and an anode. Continuous **modulation** of the anode current can be effected by variation either of the conductivity or the effective cross-section of the plasma. The first method is based upon the modulation of the electron-ionizing beam which controls the plasma density, and hence its conductivity. The second method makes use of the **gating** action of positive-ion sheaths which surround the wires of a **grid**, located between the anode and cathode.

PLASTIC. (1) Capable of being molded, i.e. changed in shape without fracture. (2) A substance which can be formed when hot, either initially only; or both initially and on reheating.

PLASTIC DEFORMATION. The permanent change in size or shape of a ductile material under stress. The deformation occurs along the slip planes of the crystals, and anything that tends to interfere with this slippage or to resist the deformation will result in an increase in tensile strength.

PLASTICIZER. A material which is added to a rocket **propellant** to increase plasticity, workability, or to extend physical properties.

PLATE. The common name for the principal anode of a **vacuum tube**.

PLATE CIRCUIT. A circuit including the plate voltage source and all other parts connected between the cathode and plate terminals of a **vacuum tube**.

PLATE DETECTION. The operation of a **vacuum tube** detector at or near plate current cut-off, so that rectification of the input signal is accomplished in the plate circuit.

PLATE RESISTANCE. The resistance (in ohms) of the path through the **vacuum tube** between the plate and the cathode. It is expressed as the ratio of the plate voltage to the plate current with the cathode voltage held constant.

PLATE SUPPLY. The power source, usually d-c, for the plate circuit of an **electron-tube** device.

PLATFORM, STABILIZED. Gyroscope, stabilized platform.

PLATINUM. Metallic element. Symbol Pt. Atomic number 78.

PLAYBACK. The reproduction of a magnetic tape recording for the purpose of reconstructing the original signals as faithfully as possible. A playback is usually an oscillograph trace made from a magnetic tape. It is a "raw data playback" if it is fed through a **discriminator** and **decommutator** directly onto the oscillograph. It is a "linearized playback" if it has all **bias** removed by appropriate corrections.

PLENUM (CONDITION). A condition in which the pressure of the air in an enclosed space or duct is greater than that of the outside atmosphere.

PLENUM CHAMBER. An air chamber opening into the **compressor chamber** on certain turbojet or turboprop engines, and in which air is collected for the compressor.

PLOTTING BOARD. An electromechanical device actuated by electrical impulses proportional to a mathematical function, and cap-

able, by means of automatically controlled pens or other drawing devices, of tracing a graphical representation of the function. The usual automatic plotting board has two movable arms carrying pens which travel up and down them. The arms move across a paper chart, and the combined movement of the arms and pens can reproduce any curve in two dimensions. Sometimes one of the required motions, usually time, is achieved by moving the paper under the pens.

PLOVER. A U.S. target drone missile using a ramjet propulsion system developed by the Glenn L. Martin Company. It evolved from the **Gorgon IV** as a prototype.

PLUMBING. (1) In missile and radar usage, the designation for waveguides, coaxial lines and other equipment used for transmission of radio-frequency energy. (2) The piping, lines and connections associated with the engine and its control. (3) The piping lines and connections associated with the hydraulic system.

PLUTO. (For table of planetary data, see **planet**.) The planet of the solar system that is most distant from the Sun. It takes 248 earth years to complete its orbit. It is thought to be about 3600 miles in diameter, and to have a temperature near absolute zero.

PLUTONIUM. Transuranium radioactive element. Symbol Pu. Atomic number 94.

PM. Modulation, pulse.

Pm. Promethium.

Po. Polonium.

POC. Production operational capability.

POLONIUM. Radioactive element. Symbol Po. Atomic number 84.

PNEUDRAULIC. Of or pertaining to a combination of pneumatic and hydraulic, e.g., a pneudraulic device operates on combined pneumatic and hydraulic systems.

PNEUMATIC. Of or pertaining to air, particularly to compressed air or air used as a working fluid in some mechanical system. The term is also applied to systems where the working fluid is some other gas than air.

POGO. A U.S. Navy rocket carrying a parachute that can be shot to a height of 60,000 feet to be used as a target for guided missiles such as the **Nike**. The missile was $13\frac{1}{2}$ feet long. Pogo-Hi was a small target rocket of better performance.

POID. The curve traced by the center of a sphere when it rolls over a surface having a sinusoidal profile.

POINT CONTACT TRANSISTOR. Transistor, point contact.

POINT, IMAGE. Image point.

POINT, IMPACT. Impact point.

POINT SOURCE. No finite source of radiation is a true point, but any source viewed from a distance sufficiently great compared to the linear size of the source may be considered as a point source. In the distance range in which measurements of the radiation from a source show that it obeys the inverse square law (no absorption), then to the accuracy of the measurements, the source may be considered as a point source.

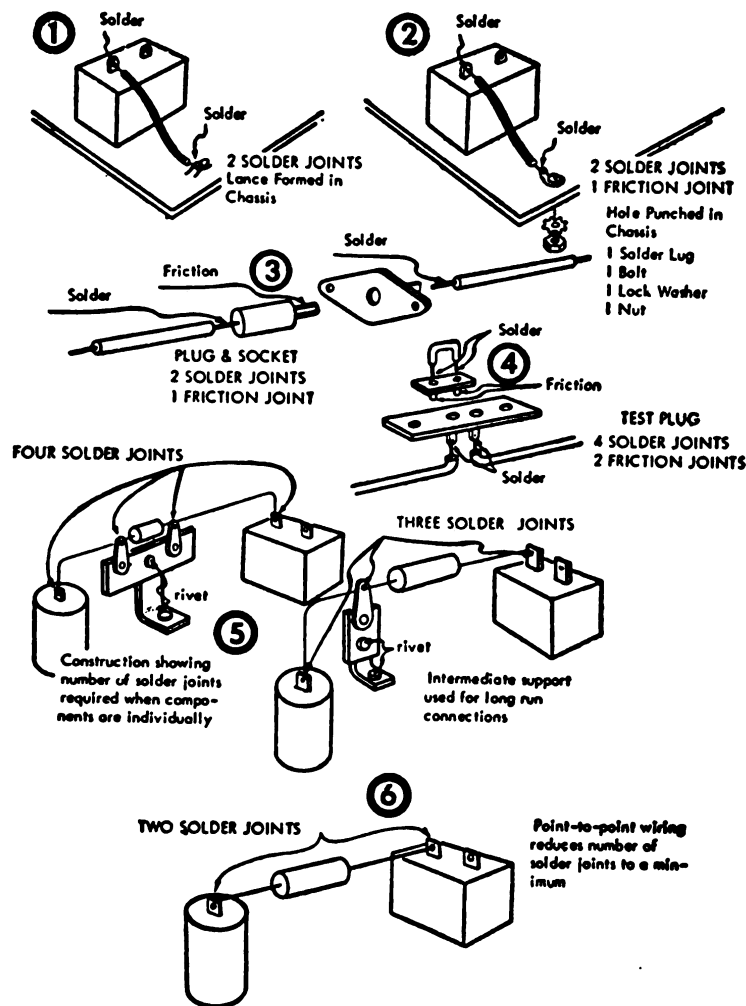
POINT-TO-POINT WIRING. A production technique for wiring electronic chassis in which the connections between components or parts are made without intermediate supports. (See Figure on Page 457.)

POISE. A unit of viscosity equal to 1 gram per centimeter-second.

POLAR CHART. A map in which either the north or south pole is the central point and usually the point of tangency chosen for the projection. There are several types of polar charts all having the same appearance. These are: polar gnomonic, azimuthal equidistant, and stereographic.

POLAR CONTINENTAL AIR. Polar air that originates over a continent and remains relatively stable and dry as it moves over a continental area.

POLAR COORDINATES. If r is the distance from the origin of a rectangular Cartesian coordinate system to a point (x,y,z) and if the direction angles of a line drawn from the origin to the point are α, β, γ then the polar coordinates of the point are given by



Comparison of point-to-point wiring with other methods.

$$x = r \cos \alpha; \quad y = r \cos \beta; \quad z = r \cos \gamma;$$

$$r^2 = x^2 + y^2 + z^2.$$

Further relations also exist and the system is generally called spherical polar coordinates.

If the point lies in a plane determined by a pair of the coordinates, the XY-plane for instance, then $z = 0$, and with the usual symbols, $\alpha = \beta = (\pi - \theta)$

$$x = r \cos \theta; \quad y = r \sin \theta; \quad \theta = \tan^{-1} y/x.$$

The coordinate origin is called the pole; the X-axis is the polar axis; the angle θ is the polar or vectorial angle (sometimes the azimuth of the point); r is the radius vector. Complex numbers are often plotted in this way, the vectorial angle then being called the amplitude, argument or phase and the radius vector is the modulus.

POLAR FRONT. A front or frontal surface between polar air masses and warmer air masses to the south.

POLAR GNOMONIC PROJECTION. A method of portraying the earth's surface. If the pole is chosen as the point of tangency for a gnomonic projection, the meridians appear as radial lines and the parallels of latitude appear as concentric circles. It is also called a "Polar Gnomonic Chart."

POLAR MARITIME AIR. Polar air that moves south over an ocean area, acquiring a relatively high moisture content and becoming unstable.

POLARIS. (1) In astronomy, the pole star. It lies almost on an extension of the axis of the earth in the direction of north and so

does not shift in relative position perceptibly from year to year. It may be located in the sky as being the brightest star approximately seven times the distance between the two cup stars of the Big Dipper, measured from the outermost in a direct prolongation of the ("lip") line established by the two stars. (2) The U.S. Navy fleet ballistic missile (FBM) project announced in the fall of 1956. It consisted of a solid propellant type rocket having an IRBM capability when launched from a submerged submarine. The Lockheed Aircraft Corporation's Missiles Systems Division received the contract to develop the Polaris. General Electric Company and Massachusetts Institute of Technology received contracts to develop the guidance and fire control equipment. Test vehicle firings began at Cape Canaveral, Florida in September 1957. The Navy reported in 1958 that the Polaris program was more than a year ahead of schedule and that the missile should be operational with the fleet in 1960. Published reports indicated that the Polaris would be a two stage vehicle about 28 feet long, about 5 feet in diameter and weighing about 14 tons. The submarine launching scheme called for the missiles to be ejected from tubes by compressed air and to ignite after breaking the surface of the water. (See **missile, guided**.) (See also illustration facing Page 314.)

POLARIZATION, VERTICAL AND HORIZONTAL. In optics, to avoid ambiguity it is preferable to describe vertical and horizontal polarization as parallel and perpendicular, respectively, to the plane of incidence (the plane containing the incident and reflected rays).

POLARIZED LIGHT. Light, plane-polarized; light, elliptically-polarized; and light, circularly-polarized.

POLYCONIC PROJECTION. A method of portraying the earth's surface. The projection is made on a series of cones tangent to the earth. Meridians, except the central one, are represented as curved lines. Parallels of latitude are nonconcentric circles, which have their centers along the central meridians, usually beyond the limit of the map. There is no distortion along the central meridian and, unless the spread in longitude is great, maximum distortion is small. The polyconic projection is not suitable for navigational pur-

poses, because both direction and distance are difficult to measure accurately, and both **rhumb lines** and **great circles** are curves.

POLYTROPIC PROCESSES. The expansion or compression of a constant weight of gas may assume a variety of forms, depending on the extent to which heat is added to or rejected from the gas during the process, and also on the work done. There are, theoretically, an infinite number of ways possible in which a gas may expand from an initial pressure p_1 , and volume v_1 to a final volume v_2 . All these expansions may be grouped generically as polytropic expansions, and all could be represented graphically on the PV plane by the family of curves $pv^n = C$. They are all, in theory, perfectly reversible. n may have any positive value, 0 to ∞ , and having been selected numerically it defines the type of expansion. From the infinite number of possible polytropic expansions, it is worth while to isolate four which deserve special attention. When one of the four physical characteristics, to wit, **pressure**, **temperature**, **entropy**, or volume, remains constant, expansions of more than ordinary interest are denoted, since they are frequently employed in a practical way, in situations which can be subjected to thermodynamic analysis. The value of the exponent n of the polytropic family for each of these is:

Isobaric	$n = 0$,
Isothermal	$n = 1$,
Isentropic	$n = \gamma$ (γ = ratio of specific heat at constant pressure to that at constant volume)
Isometric	$n = \infty$.

POROSITY. (1) The property of containing pores, which are minute channels or open spaces in a solid. (2) The proportion of the total volume occupied by such pores.

POROUS REACTOR. Reactor, porous.

PORT AREA. In rocketry, the cross-sectional area perpendicular to the longitudinal axis of rocket propellant grain available for free gas flow.

POSITION. A concept which implies the possibility of locating a particle in public space with respect to a reference system.

POSITION DATA. Successive data defining the position of a target being tracked by radar or other means.

POSITION FEEDBACK. Feedback, position.

POSITRON. A positive electron. Positrons are formed in **pair production**, by the radioactive decay of many nuclides and in other processes.

POST, CAPACITIVE. A **waveguide** tuning or matching device which consists of a metal post or screw extending completely across the waveguide at right angles to the E-field. In this position the post adds capacitive **susceptance** in parallel with the guide.

POST, INDUCTIVE. A **waveguide** tuning or matching device which consists of a metal post or screw extending completely across the waveguide parallel to the E-field. In this position the post adds inductive **susceptance** in parallel with the guide.

POTASSIUM. Metallic element. Symbol K. Atomic number 19.

POTASSIUM PERCHLORATE. A chemical compound of formula KClO_4 . It is a colorless crystalline powder with a specific gravity of 2.524 at 11°C . It is used in many types of **solid propellants**. Potassium perchlorate is only slightly soluble in water, and thus is not hygroscopic (a good quality for solid propellants under field conditions).

POTASSIUM PERMANGANATE. A dark purple crystalline solid of specific gravity 2.70, and formula KMnO_4 . It is a strong oxidizing agent. It is used also as a catalyst for decomposing hydrogen peroxide.

POTENTIAL. Among its many meanings and connotations, this term is used commonly in science as an adjective with the meaning of available, rather than in action or use, as potential energy (energy of position or state) as opposed to kinetic energy. The term potential is also used as a substantive, and in this sense designates the name of a number of different quantities used in physics, such as electric potential (see **potential, electric**), magnetic potential, nuclear potential (see **potential, nuclear**) and gravitational or mass potential, the latter being defined at any point

as the energy necessary to carry a unit mass from that point to a region of space infinitely removed from all matter. Its value is the integral of $G(dm/r)$, where G is the **gravitational constant**, dm is any mass element, and r is the distance from the point in question; the integration being extended throughout all existing matter. Electric potential and magnetic potential at a point are defined as the energy necessary to carry unit charge, or unit pole, respectively, from infinity to that point. The "Newtonian potential function" is a mathematical expression occurring as a factor in all these potentials.

A characteristic of the mass potential, the electric potential, and the magnetic potential, is that in each case the first derivative of the potential with respect to any direction, as x , at any point in space, is equal in magnitude to the component of the field intensity in that direction at the point in question.

The foregoing potentials all involve inverse-square forces; if the field obeys the inverse-first-power law, the potential involves the logarithm of the distance, and is called the "logarithmic potential."

By analogy, we have also a so-called "thermodynamic potential," which, in reference to a substance in any state, represents the energy which has been required to bring unit mass of the substance to the state in question from some arbitrarily defined, initial state.

In physics, a "potential field" is a vector field derivable from a scalar potential, as $\mathbf{E} = \nabla \phi$. Any vector \mathbf{V} such that $\nabla \times \mathbf{V} = 0$ can be so expressed. Conversely, any vector \mathbf{B} such that $\nabla \cdot \mathbf{B} = 0$, can be expressed as $\mathbf{B} = \nabla \times \mathbf{A}$, as in magnetostatic field. \mathbf{A} is called a vector potential.

POTENTIAL DIFFERENCE. Consider a **direct-current** electric circuit divided into two parts: (1) a box containing sources of emf and (2) a box containing no sources. The potential difference across the common terminals of these boxes is

$$V = IR_L = \mathcal{E} - IR_g$$

where I is the current, R_L the resistance of the "load" box, \mathcal{E} the emf of the "generator" box, and R_g the resistance of the "generator."

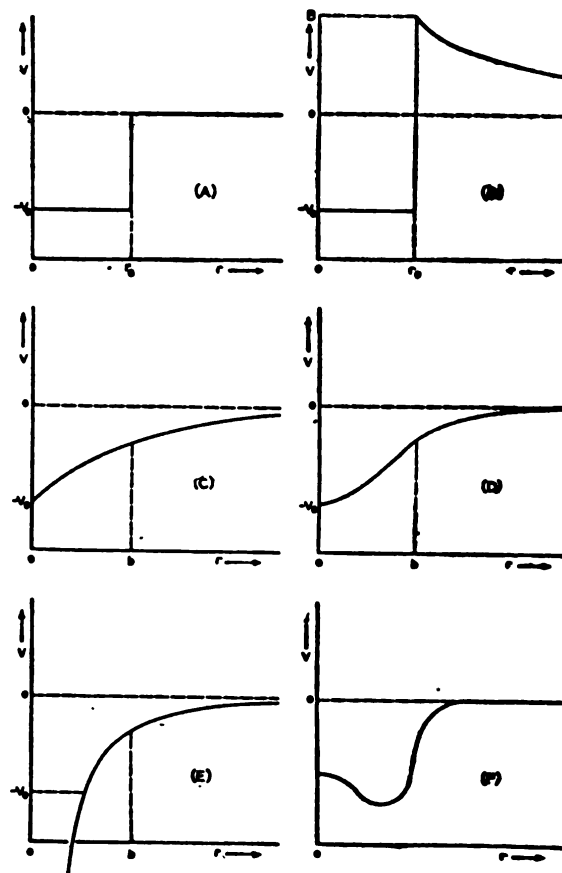
POTENTIAL, ELECTRIC. If a charge of electricity is moved from one region of space

to another, it encounters, in general, electric forces which either help or hinder the transfer and which therefore add to or subtract from the potential energy of the charge. Suppose that a positive unit charge has been brought into the region *A* from a region so remotely beyond the borders of the material universe that no electric forces exist there. In general, a certain amount of work, V_A , has been done against the electric forces encountered on the way in; consequently V_A may be regarded as the potential energy which the unit charge has acquired in the process. This work per unit charge, V_A , is called the absolute electric potential of the region *A*. It is a scalar quantity, and may be either positive or negative; for example if *A* is in the vicinity of a large negative charge, the unit positive charge has been attracted and has done work, or lost potential energy, during its journey, and V_A is therefore negative. If a second region *B* is at a potential V_B , less than V_A , the unit charge would lose potential energy in moving from *A* to *B*, in the amount $V_A - V_B$. Thus, in an electrolytic cell, a positive ion migrates from the high-potential to the low-potential electrode, and does work in heating the solution. Negative charges tend to migrate from lower- to higher-potential regions; this is illustrated by the electrons in a wire.

The absolute zero of potential is of course that at an infinite distance from the universe; but for practical purposes an arbitrary zero is used, commonly that of the earth's surface (which is by no means constant); or that of some other large conductor, such as the metallic base or case of the apparatus being used. The ordinary unit of electric potential is the volt.

POTENTIAL, NUCLEAR. The potential energy V of a nuclear particle as a function of its position in the field of a nucleus or of another nuclear particle. A central potential is one that is spherically symmetric; that is, V is a function only of the distance r from the center of the field, thus being the same in all directions, and is representable by a curve as in Figs. (A)-(F). A potential well is the region about a minimum in the potential; it results from attractive forces. A potential barrier is the region about a maximum in the potential; it results from repulsive forces, either alone or in combination with attractive forces. Some central potentials

commonly used as approximations to nuclear potentials are illustrated in the figures. (A) shows a square well potential, which has a constant negative value $-V_0$ for $r \leq r_0$ and zero value for $r \geq r_0$. When this curve represents the potential between two nucleons, r_0 is called the range of nuclear forces; when it represents the potential of a nucleus, for a nucleon, r_0 is called the nuclear radius. (B) shows a square well potential for $r \leq r_0$ with a Coulomb potential resulting from repulsive electrostatic forces, for $r > r_0$. The resulting



barrier is called a Coulomb barrier, and the maximum energy B is called the barrier height. Such a potential approximates that of a positively charged particle in the field of a nucleus, and is often used in the theory of α -disintegration and nuclear reactions. (C) shows an exponential well, $V = V_0e^{-r/b}$, (D) shows a Gaussian well, $V = V_0e^{-r^2/b^2}$. (E) shows a Yukawa potential, $V = -(V_0/r)e^{-r/b}$ used in the meson theory of nuclear forces for the interaction between two nucleons. (F) shows a wine-bottle potential, characterized by a low central elevation. If a high

central elevation is present, the resulting barrier is called a central barrier.

POTENTIAL OF A FIELD OF FORCE.

Potential energy per unit mass for a gravitational field of force or per unit charge for an electrostatic field of force.

POTENTIOMETER. A device for translating a quantitative motion (angular or linear) into a proportional electrical resistance; it measures by comparing the difference between known and unknown electrical potentials.

POTTING. The process of imbedding an electronic circuit component or assembly in a (usually) plastic material to reduce susceptibility to deleterious environments, simplify maintenance, etc.

POUND. A unit of mass in the English system of weights and measures. Unless specified otherwise, it is understood to be the avoirdupois pound of 453.59 grams, rather than the troy pound of 373.24 grams. It is also used as a unit of force, in which case it is the weight of one pound at a location where $g = 32.174 \text{ ft/sec}^2$ (cf. **poundal**).

POUNDAL. A unit of force in the f lbm s system, being the force which imparts an acceleration of 1 ft/sec^2 to a mass of one pound. Equal to $1 \text{ lbf}/32.174$.

POWER. (1) The rate of doing work. (2) A dry explosive or propellant, often in the form of numerous fine particles, but sometimes in the form of one or more large pieces.

POWER AMPLIFIER. Amplifier, power.

POWER FACTOR. In alternating current networks, the (mean) power is $EI \cos \theta$, where θ is the phase difference between E and I . The multiplying factor, $\cos \theta$, is the power factor.

POWER GAIN. The ratio of the power that a **transducer** delivers to a specified load, under specified operating conditions, to the power absorbed by its input circuit. If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting should be specified. This gain is usually expressed in **decibels**.

POWER LEVEL. At any point in a transmission system, the difference of the measure of the steady state power at that point from the measure of an arbitrarily specified amount of power chosen as a reference. In audio techniques, the measures are often expressed in decibels, thus their difference is conveniently expressed as a ratio. Hence, power level is widely regarded as the ratio of the steady state power at some point in a system to an arbitrary amount of power chosen as a reference.

POWER LOADING. In the aerodynamics of airplanes, the ratio of total horsepower to wing area.

POWER LOSS. The ratio of the power, absorbed by the input circuit of a transducer to the power delivered to a specified load under specified operating conditions. If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting should be specified. This loss is usually expressed in **decibels**.

POWER OUTPUT, PEAK. The output power averaged over a carrier cycle at the maximum amplitude which can occur with any combination of signals to be transmitted.

POWER, PEAK PULSE. Peak pulse power.

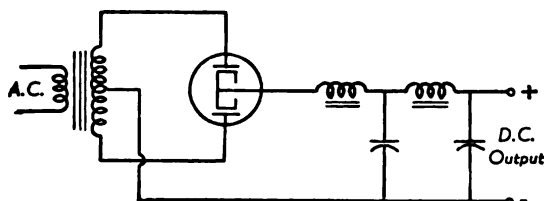
POWER SPECTRAL DENSITY. Limiting mean square acceleration (velocity, displacement, stress or other random variable) per unit bandwidth, i.e., the limit of the mean square acceleration in a given rectangular bandwidth, divided by the bandwidth as the bandwidth approaches zero.

$$PSD = \lim_{\Delta f \rightarrow 0} \frac{\overline{a^2}(\Delta f, f)}{\Delta f}$$

POWER STANDING WAVE RATIO. Standing wave ratio.

POWER SUPPLY. This term is widely used to denote a circuit for converting a-c into d-c by electronic means. The usual power supply consists of a **transformer** for changing the a-c voltage to a value which will, when rectified and filtered, give the desired value of d-c, rectifier tube or tubes, and a **filter** consisting of inductance in series and capacitance in shunt with the d-c line. A typical circuit is

shown. The output of the rectifier is pulsating d-c and hence needs to be smoothed out by the filter before it is suitable for many applications. Power supplies of this type are almost universal components of radios, **amplifiers** and other vacuum-tube devices which operate from a-c mains.



POWER SUPPLY, STATIC. A non-rotating alternating current power supply.

POWERED-ALL-THE-WAY (PAW) ASCENT. This path of ascent, as shown in the illustration given in the article on **elliptic ascent**, is the most direct and shortest line of travel from a point on earth to a point in an orbit. Therefore it requires the greatest power and a fuel expenditure so great that it is too expensive for ascent into orbits that lie much above 125 to 130 nautical miles above the surface of the earth. In this connection it should be said that for a given time of ascent, the optimum trajectory for the particular thrust program and staging system, including the effect of drag and gravitational tracking, must be determined in order to minimize the propellant requirement. If tracking is required during powered flight, the powered trajectory may have to be optimum for tracking. A number of complex detailed problems must be solved in connection with stability, and in the unavoidable elasticity of large thin-shelled vehicles.

POYNTING VECTOR AND THEOREM. Manipulation of the **Maxwell equations** yields a relation known as the Poynting theorem:

$$\int_S (\mathbf{E} \times \mathbf{H}) \cdot \mathbf{n} d\mathbf{a} + \int_V \mathbf{E} \cdot \mathbf{J} dV \\ = - \int_V \left\{ \mathbf{E} \cdot \frac{\partial \mathbf{D}}{\partial t} + \mathbf{H} \cdot \frac{\partial \mathbf{B}}{\partial t} \right\} dV,$$

where \mathbf{n} is the unit vector normal to the surface S that bounds the volume V . The customary interpretation of this result is that the right-hand side represents the rate of loss of electric and magnetic energy stored in the

volume V , that the second term on the left represents the rate of dissipation of electrical energy as Joule heat in V , and that the first term represents the balancing flow of electromagnetic energy through the surface S bounding the volume. It is often convenient to assume that the Poynting vector

$$\mathbf{P} = \mathbf{E} \times \mathbf{H}$$

represents the power flow per unit area in the direction \mathbf{P} . This resolution of the total outward power flow is not unique, and is not acceptable when applied to an electrically-charged permanent **magnet**, but is notably successful in treating electromagnetic radiation problems.

PPI. Plan position indicator; present position indicator.

Pr. Praseodymium.

PRACTICE ROCKET. A rocket used in practice or training, having either an inert warhead or a head containing a spotting charge, but otherwise having the same characteristics as the corresponding service rocket.

PRANDTL-GLAUERT EFFECT. In aerodynamics, the phenomenon of increased lift due to the **compressibility** effects encountered in high subsonic flight.

PRANDTL-GLAUERT LAW. In aerodynamics, a relationship for the effect of compressibility on the lift of a two-dimensional wing. It is not exactly rigorous, i.e., the assumptions break down if local supersonic flow is obtained. Also, the relationship does not apply to thick wings (i.e., wings for which $t/c = 20\%$ or more).

PRANDTL NUMBER. An aerodynamic parameter, defined by the equation:

$$Pr = \frac{C_p \rho_o V L}{\lambda} \frac{1}{Re} = \frac{C_p \mu}{\lambda}$$

where Pr is the Prandtl number, C_p is the specific heat at constant pressure, ρ_o is the density, V is the velocity of flow, L is the typical linear dimension, Re is the Reynolds number, μ is the coefficient of viscosity, and λ is the coefficient of heat conduction (thermal conductivity).

Typical Pr numbers for air are:

TEMPERATURE	PRANDTL NUMBER	TEMPERATURE	PRANDTL NUMBER
0°C	0.769	300°C	0.719
100°C	0.760	400°C	0.621
200°C	0.767	500°C	0.521

PRASEODYMIUM. Rare earth element. Symbol Pr. Atomic number 59.

PREAMPLIFIER. An extra stage of amplification at the front end of an amplifier or receiver used to increase signal strength.

PRECESSION. A change in the orientation of the axis of a rotating body, such as a spinning projectile or gyroscope, the effect of which is to rotate this axis (axis of spin) about a line (axis of precession) perpendicular to its original direction and to the axis (axis of torque) of the moment producing that change. (See **gyroscope**, and **gyroscope, displacement**, and their illustrations.)

PRECIPITATION. (1) The act or process by which moisture in the air condenses and falls. (2) The condensed droplets or particles of moisture that fall on the earth's surface.

PRECISION. Quality of being exactly or sharply defined or stated. A measure of the precision of a representation is the number of the distinguishable alternatives from which it was selected. The precision of measurement is the degree of reproducibility among several independent measurements of the same true value under specified conditions.

PRECISION APPROACH RADAR. A radar on the ground, used in ground-controlled approach to display continuous information regarding the distance, azimuth, and elevation of a vehicle moving along the approach path.

PRECOMBUSTION CHAMBER. In a rocket, a chamber in which the propellants are ignited and from which the burning mixture expands torchlike to ignite the mixture in the main chamber.

PRECOOLING. The reduction of temperature in a container (e.g., missile propellant system) to prepare it for filling with extremely cold materials, e.g., liquid oxygen, liquid nitrogen, or liquid hydrogen. Precooling avoids thermal shock problems when introducing cold liquids into a "hot" container.

PREDICTOR. In artillery terminology, a computing device which accepts as continuous inputs the successive positions of a moving target, and which gives future positions or predicts positions over various periods called "predicting intervals." The predictor was used in seacoast artillery fire control, but is not a modern device. A modern instrument to perform the same operation is usually called a **computer**.

PREDICTOR, IMPACT. Impact predictor.

PRE-LAUNCH CONSOLE. A display panel and control panel housed in the blockhouse, that monitors or checks out a missile during the **count-down** prior to actual launch.

PRELIMINARY DESIGN. That design phase which has for its objective the establishment of the basic configuration and resultant performance of the missile and its auxiliary equipments.

PREMATURE DETONATION. A **detonation** of a warhead prior to the time that the **S** and **A** was to arm the system.

PREPROTOTYPE. A device, article, assembly, or system which precedes the **actual prototype**. In terms of time, the preprototype usually follows the **breadboard**, and is functionally correct in about the right package and proportion. Generally the device has not been designed for environment, maintenance and other features usually found in a prototype article.

PRE-SELECTOR. A **pre-amplifier** placed between the antenna and a radio-receiver to increase the effective **sensitivity** and **selectivity** of the receiver.

PRESENT POSITION INDICATOR (PPI). A device or system with computational features used to establish, for fire control or guidance systems, an indication of the present position of the missile target.

PRESENTED TARGET AREA. The projection of a target upon the perpendicular plane used in defining the dispersion area. It is used to analyze the performance requirements of an armament system.

PRESET GUIDANCE. A type of **guidance** for aircraft, rockets or **guided missiles** in

which the path of the missile is determined by controls set before launching. The mechanism for this type of guidance usually consists of **gyroscopes**, integrating **accelerometers**, and related devices.

PRESSURE. A type of stress, characterized by its uniformity in all directions (as distinguished from compressive stress in one direction). Its measure, as with all other stresses, is the force exerted per unit area; for example, the normal **atmospheric pressure** is about 14.7 lbf per sq in. Pressure is usually associated with a decrease in volume; though the opposite stress, accompanying an increase in volume, is sometimes referred to as "negative pressure." This latter must be distinguished from the same term as sometimes used to denote pressures below atmospheric, the pressure of the atmosphere being in such cases taken as an arbitrary zero. It is likewise important, especially in pneumatics, to indicate whether pressure is reckoned from vacuum or from atmospheric pressure as zero. Thus when a tire is inflated to "thirty-five pounds," the actual pressure in the tire is about 50 lbf per sq in. Pressure may be defined analytically as that part of the **stress tensor** that does not depend directly on the rate of strain and which arises from the molecular movements appropriate to the local density and temperature, i.e., the pressure satisfying the equation of state. In a compressible Newtonian fluid (see **fluid, Newtonian**), the stress tensor is

$$p_{ij} = \eta \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) - \left(\frac{2}{3} \eta' \frac{\partial u_i}{\partial x_i} + p \right) \delta_{ij}$$

where η is the ordinary viscosity, and η' is the second coefficient of viscosity. In agreement with the definition above, the pressure p contributes only to the normal stresses.

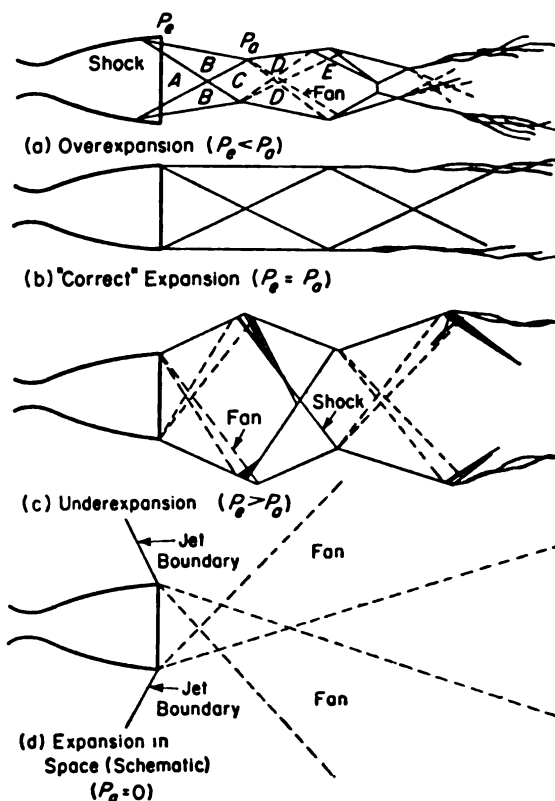
PRESSURE ALTITUDE. (1) Altitude above the standard datum plane, i.e., altitude measured from standard sea-level pressure (29.92" Hg) by a pressure, or barometric, altimeter. Although this altitude may be either an indicated altitude or a calibrated altitude, it is commonly considered to be calibrated. (2) The altitude in a standard atmosphere corresponding to a given atmospheric pressure actually encountered. It is usually determined by applying the standard pressure **lapse rate** to the atmospheric pressure at altitude. Pressure altitude is the same as true

altitude only when the pressure lapse rate is standard. (3) The simulated altitude condition created in an altitude chamber by changing (usually by lowering) the pressure in the chamber.

PRESSURE ALTITUDE VARIATION. The difference in feet between the standard datum plane (29.92 inches of mercury) and the datum plane above which altitude is measured.

PRESSURE, AMBIENT. The undisturbed pressure of a fluid in which a vehicle moves. Usually it must be measured at a distance from the vehicle to avoid interference effects.

PRESSURE, AMBIENT, NOZZLE EFFECTS OF. Ideally the exit pressure of a nozzle p_e should equal the ambient pressure p_a . The effects of variation from this ideal are shown in the illustration. In figure (a) the nozzle area ratio is so large that the gas pressure at the exit, p_e , is appreciably below the ambient pressure, p_a . The gas is over-expanded. A certain amount of over-expansion is tolerated by the gas. In that case the flow fills the entire nozzle, but since $p_e < p_a$,



Appearance of Exhaust Jets in Various Ambient Pressures

a negative pressure thrust is produced. With increasing overexpansion the gas finally reaches a point where the momentum of the flow in the boundary layer can no longer overcome the adverse pressure gradient, caused by the high back pressure. The boundary layer separates from the wall (jet detachment) and expansion ceases at the line of separation. The separation is accompanied by oblique shock waves, because the jet expansion ceases; this amounts to an inward bending of the streamlines compared to their original flow direction. The expansion pattern is destroyed by the shock waves which cause a departure from isentropic conditions. The exhaust velocity is slightly decreased, depending on the strength (steepness) of the shock wave. As the shock waves hit the opposite stream boundary, they are reflected as expansion fans and then back again as shock waves. The shock waves with their higher pressure cause a contraction of the jet to approach the higher ambient pressure. The flow in the field *A* "knows" nothing about the processes downstream (since the flow is supersonic and disturbances can therefore not be propagated upstream). In region *B* the flow has passed one shock wave and the pressure is brought up to a value close to ambient. However, in region *C* the flow has passed two shock waves because of the crossing of the oblique waves. The pressure is now too high. As the shock waves are reflected as expansion fans on a jet boundary, the flow expands from *C* to *D* and the pressure relaxes back to a value close to the one in region *B*. Because of the cross-over of the expansion fans overexpansion takes place, and in region *E* the pressure is a minimum, approximating the pressure in region *A*. Since an expansion fan is reflected as a shock wave on a jet boundary, recompression sets in and a new cycle begins. These cycles are responsible for the alternate contraction and expansion of the jet. They would continue *ad infinitum* if it were not for the damping effect of friction and admixture of cool gases from the outside which gradually dissolve the jet. The situations for correct expansion, underexpansion and expansion in space can be similarly analyzed.

PRESSURE ANOMALY. The difference between the actual pressure lapse rate and the arbitrary standard pressure lapse rate for which an altimeter is designed.

PRESSURE BREATHING. The breathing of oxygen or other suitable gases through a special system or apparatus at a pressure in excess of the ambient atmospheric pressure.

PRESSURE COEFFICIENT. A non-dimensional product given by the equation:

$$P = \frac{F}{\rho V^2 L^2} = \frac{p}{\rho V^2}$$

where *P* is the pressure coefficient, *p* is the pressure, *F* is the force, *ρ* is the density, *V* is the velocity, and *L* is the length.

PRESSURE-DEMAND OXYGEN EQUIPMENT. A kind of low-pressure oxygen equipment that functions either as demand oxygen equipment or as continuous-pressure breathing equipment. (See **oxygen equipment**.)

PRESSURE FEED SYSTEM. In liquid rocket engines, the system used to cause the **propellants** to flow to the combustion chamber.

PRESSURE FRONT. Shock front.

PRESSURE GAS. In a liquid-fuel rocket, a gas fed under pressure into the fuel tanks to force the fuel into the combustion chamber.

PRESSURE GRADIENT. The rate of pressure increase or decrease on any atmospheric plane, usually a horizontal plane, for any given distance. (See **barometric pressure gradient**.)

PRESSURE, GAUGE. Pressure measured relative to atmospheric pressure taken as zero.

PRESSURE, IMPACT. Pressure exerted by a moving fluid on a plane perpendicular to its direction of flow. In other words, it is measured in the direction of flow.

PRESSURE JET. A kind of cup or a small combustion chamber at or near the tip of a rotor blade, which turns the rotor by ejecting a fluid jet. The pressure jet may eject compressed air or exhaust gases from a central power plant or exhaust gases from combustion occurring inside the chamber.

PRESSURE LIMIT. The upper and lower chamber pressure limit within which a **solid propellant** will operate satisfactorily.

PRESSURE, NEGATIVE. Strictly, a normal stress that tends to increase the volume of the substance (cf. **pressure**). The term is often used, however, to indicate a negative gauge pressure, i.e., a pressure that is less than atmospheric, or a pressure less than 760 millimeters of mercury at 0°C.

PRESSURE, PARTIAL. The pressure that is exerted by a single gaseous **component** of a mixture of gases.

PRESSURE RECOVERY. In aerodynamics, the process of obtaining pressure increases through the blocking or partial blocking of the channel through which the air or other fluid must flow. In supersonic aerodynamics, pressure recovery is obtained by the use of different types of **diffusers**.

PRESSURE, SOUND (ACOUSTOMOTIVE). **Sound (Acoustomotive) pressure.**

PRESSURE, STATIC. (1) Pressure in a fluid or system that is exerted normal to the surface on which it acts. In a moving fluid, the static pressure is measured at right angles to the direction of flow. (2) In acoustics, the static pressure at a point in a medium is the pressure that would exist at that point with no sound waves present. In acoustics, the commonly used unit is the **microbar**.

PRESSURE SUIT. A suit designed to maintain pressure over all or part of the body under conditions of low ambient pressure. (Cf. **g-suit**.)

PRESSURE THRUST. Thrust, pressure.

PRESSURE, VELOCITY. The component of the pressure of the moving fluid that is due to its velocity and is commonly equal to the difference between the impact pressure and the static pressure. (See **pressure**, **impact**, and **pressure, static** (1).)

PRESSURIZE. (1) To produce and maintain in a cockpit, cabin or compartment of a vehicle, or in a special garment, an air pressure higher than the ambient atmospheric pressure, in order to compensate for the lowered pressure at high altitudes; to create a higher pressure in the air within a cockpit, cabin, etc., by the introduction of additional air. (2) In pressure-fed propellant systems, that phase of operation in which the pres-

surizing gas is applied to the propellant to cause it to feed to the pumps or combustion chamber, or to prevent boiloff or vaporization.

PRESTAGE. A phase in starting liquid rocket engines in which combustion is initiated and combustion chamber pressure is developed to a predetermined level at which time **main stage** is initiated.

PREVAILING WESTERLIES. Winds that blow northwesterly toward the poles from the **horse latitudes**. They are not as steady as the trade winds in the Northern Hemisphere, but they are more constant in the Southern Hemisphere, where they are known as the "Roaring Forties."

PREVOST LAW. When two bodies are in radiation equilibrium, the rate at which the first radiates to the second is the same as the rate at which the second radiates to the first.

PRF. (Radar) Pulse repetition frequencies.

PRIMACORD. An explosive charge, shaped like a rope, used in flight missiles to sever structure for flight termination purposes. It is also used to sever control links, booster assemblies, etc.

PRIMARY SKIP ZONE. That area surrounding a **transmitter** which is beyond ground-range, but where sporadic skip transmission may be received.

PRIMARY STRUCTURE. The main framework, including fittings and attachments. Any structural member, the failure of which would seriously impair the safety of the missile, is a part of the primary structure.

PRIMARY WINDING. Any winding of a **transformer** used as the input port for power is called the "primary" winding. Transformers designed for specific applications often have one set of terminals labeled "primary" to indicate normal usage.

PRIME CONTRACTOR. A contractor having a contract directly with the Government or other funding agency. Contrast with a **subcontractor** who has a contract with a prime contractor.

PRIME MERIDIAN. A meridian from which **longitude** is measured. In English-speaking

countries and in many other countries, the **Greenwich meridian** is used as the prime meridian.

PRIMER. (1) The first sensitive explosive element in an explosive chain which is initiated by low-level fuze output signals. (2) A primer pump.

PRINCIPAL MODES. Coupled modes.

PRINCIPAL PLANES. The three mutually perpendicular planes through a point in a stressed body on which the stresses are purely normal, i.e., tension or compression. Of these principal stresses, one is a maximum and one is a minimum. When one principal stress is zero, a state of plane stress exists; when two are zero, a state of uniaxial stress exists.

PRINCIPAL E PLANE. In electromagnetics, a plane containing the direction of maximum radiation, and in which the electric vector everywhere lies in the plane.

PRINCIPAL H PLANE. In electromagnetics, a plane containing the direction of maximum radiation, and in which the electric vector is everywhere normal to the plane, while the magnetic vector lies in the plane.

PRINTED CIRCUITRY. A generic classification for fabricated wiring which may be obtained by:

- Metal to plastic laminate etching
- Silk screening
- Photo-offset printing
- Plating
- Stamping
- Electroforming
- Embossing
- Spraying

PRISM. (1) A polyhedron with two congruent and parallel faces, the bases. Its other faces, called lateral, are produced by drawing lines from the vertices of the bases and they are therefore parallelograms. The prism is named triangular, quadrangular, etc., descriptive of its base. (2) Glass and other transparent materials are cut into many different forms of prism for various optical purposes. Incident light may pass directly through a prism, or may emerge after one or more internal reflections; in some cases it is polarized.

The common triangular prism, familiar in older forms of spectroscope, receives light upon one face and passes it through another after two refractions, resulting in a total deviation Δ dependent upon the angle of the prism and its **refractive index** for the light used. If the light is incident at angle i on the first prism face, and if the prism angle is α and the refractive index is n , the total deviation after passage through the prism in a plane at right angles to the prism edge is given by

$$\Delta = i - \alpha + \sin^{-1} \left[n \sin \left(\alpha - \sin^{-1} \frac{\sin i}{n} \right) \right].$$

PRISM, NICOL. One of the best known devices for producing **plane-polarized light**. It consists of two pieces of Iceland spar (pure calcium carbonate) cut as shown in the figure. The optic axis of each is approximately

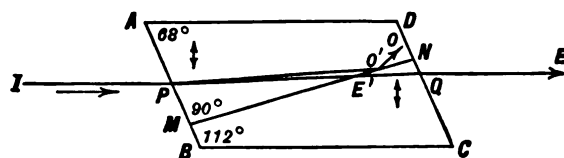


Diagram of Nicol prism. Double-headed arrows indicate direction of optic axis.

indicated by the double arrow, and they are cemented together with colorless Canada balsam along the plane MN . If the incident beam IP is unpolarized, it suffers **double refraction** at P , dividing into an ordinary component PO' and an extraordinary component PE' . The refractive index of Iceland spar for the ordinary ray (sodium light) is 1.658 and for the extraordinary it is 1.486, while that of Canada balsam for both is 1.53. The ordinary ray therefore encounters at O' a less refractive medium, and, the incidence being at an angle larger than the critical angle, it is totally reflected ($O'O$); while the extraordinary ray incident at E' encounters a more refractive medium, therefore cannot suffer total reflection and most of it passes on along $E'Q$, emerging along QE completely plane-polarized with its vibration plane in the plane of the paper. Modifications of this prism, having different shapes and using other cements, have been designed for special purposes.

PRIVATE A. A solid-propellant rocket developed by Guggenheim Aeronautical Laboratory of California Institute of Technology (GALCIT) beginning in January, 1944. It

was eight feet long, weighed 500 pounds and carried a 60 pound payload approximately 10 miles. The propulsive system was a 1000 pound thrust motor burning for 30 seconds. The motor was made by Aerojet Engineering Corporation. Take-off was assisted by four standard 4½ inch aircraft rockets. Launching was from a 36-foot rectangular steel truss boom, with four internal guide rails. The missile had four symmetrical tail fins of a 12-inch span. The nose was needle-pointed. The first missile was fired at Leach Spring, near Barstow, California, in December 1944. A total of 24 were launched. The Private A was one of the early GALCIT missiles which led to the **WAC Corporal**.

PRIVATE F. A missile of the same general design as the **Private A**. The first of these was fired in 1945. It was also made by GALCIT.

PROBABLE ERROR. A measure (pe) of the uncertainty of an experimentally determined quantity, such that the "true" value of the quantity is equally likely to depart from the measured value by more or less than pe . If the accidental errors are distributed according to the normal **error function** the probable error is defined by the integral equation

$$\text{erf}(pe) = \frac{2}{\sqrt{\pi}} \int_0^{pe} e^{-y^2} dy = \frac{1}{2}.$$

The other commonly used measures, the **average deviation** a.d. and the **standard deviation** σ are then related to the probable error:

$$pe = 0.846 \text{ a.d.} = 0.674\sigma.$$

The **circular probable error (CPE)** or **radial probable error** is a similar measure of circular dispersion. It is the radius of a circle, centered at the target within which 50% of all projectiles will fall. Circular probable error is sometimes expressed as circular error probable in which case it is abbreviated **CEP**. Radial probable error is abbreviated **PE_r**. On a normal distribution curve, the probable error = 0.6745 times the **standard deviation**. It is not the same as the mean absolute error. The probable error of any system taken as a whole is equal to the square root of the sum of the squares of all independent component errors. For example, the total probable error of a missile system might be expressed as:

$$PE_{\text{system}} = \sqrt{(PE_{\text{weapon}})^2 + (PE_{\text{location}})^2 + (PE_{\text{intelligence}})^2}$$

PROBABILITY. The chance that a certain result will occur under a defined set of circumstances.

PROBABILITY THEORY. The probability that among several equally likely events a given event will occur is the ratio of the number of favorable cases to the total number of cases. The probability of certainty is 1 and of impossibility is 0.

PROBE. (1) A small conductor inserted within a **waveguide** or resonant cavity for the purpose of exciting or coupling. (See **cavity resonance**.) (2) A small element containing an instrumental component extending before an aircraft or space ship into a region not affected by the airframe, to measure dynamic pressure or some other flight condition (e.g., total temperature, pitot-static pressure, etc.) (3) An exploratory rocket designed to travel to considerable distances through space. (See **cislunar probe**, **circumlunar probe**.)

PRODUCER'S RISK. The probability of risk of rejecting a lot, for a given lot quality or process quality, whichever is applicable. The term is usually applied only to quality values that are relatively good. (See **risk**, **producer's and consumer's**, and its graph.)

PRODUCT ENGINEERING. Translation of the development design into one suitable for efficient manufacture in the desired quantities and for the conditions of specified usage, handling, and life; the development and preparation of functional ordnance designs and/or specifications which are not only sufficiently clear and complete to represent the requirements and intent of research, but are also prepared in such manner as to facilitate efficient manufacture with the minimum of modification.

Product engineering includes such liaison with and direction over production engineering as to insure that the end product is suitable for service use, including all environmental considerations, and preparation of classification of defects.

PRODUCT RULE. The reliability of a system with n independent components can be

calculated by multiplying the individual reliabilities together, i.e.,

$$R = R_1 \times R_2 \times \cdots R_n$$

PRODUCTION. The manufacture of a finished device, built to definite specifications; the translation of the product engineering design into the desired quantity of the end product. Skilled engineering is frequently required during production to correct defects in design, to improve operating characteristics, or to increase rate of production. However, such engineering changes are based on the fundamental design created by development, which in turn was based on the facts discovered by research. The term production may be divided into the two following categories: (a) *experimental production* (including pilot line operation); (b) *mass production* (which includes the usual high production manufacturing operations).

PRODUCTION ENGINEERING. Consultation with product engineering on prototype or functional developments and designs and specifications and the making of recommendations that will promote maximum efficiency and economy in manufacture.

Participation in an advisory or consulting capacity in the preparation of detailed manufacturing drawings and specifications from which the missile can be most efficiently manufactured, having in mind not only the limited production required in time of peace but also the high rate of production with unskilled workers which is required in time of war.

The performance of the engineering function incident to efficient manufacture, such as tool and gage engineering, methods engineering, process engineering, production research, job standards.

Participation in the preparation of a Classification of Defects for quality control purposes.

PRODUCTION ENVIRONMENTAL TESTING (PET). A test technique to check workmanship in which the article or system is subjected to a reduced intensity (compared to the design requirement) environmental test.

PRODUCTION OPERATIONAL CAPABILITY (POC). A U.S. Air Force term referring to the status of a weapon system which is in the hands of troops (operational), and also in production.

PRODUCTION-TO-TARGET ENVIRONMENT. Environment, production-to-target.

PRODUCTION-TO-TARGET SEQUENCE. A chart or table showing all the steps involved in manufacture, transport, storage, maintenance in storage, withdrawal from storage, assembly prior to launch, check-out prior to launch, launch, flight, and reentry.

PROFILE. In aerodynamics, the sectional shape of an airfoil. It is the outline of the typical section that identifies the design of the airfoil.

PROFILE DRAG. That part of the airfoil drag that results from the skin friction and the shape of the airfoil as indicated by the airfoil profile. The profile drag, strictly speaking, does not include the parasite drag resulting from objects attached to the wing, but is sometimes interpreted to include such drag.

PROFILE THICKNESS. The maximum thickness of an airfoil profile.

PROFILOMETER. A device to measure the roughness of surfaces.

PROGRAM. (1) An entity; a definable portion of work; a scheduled development including study, design, fabrication and/or test phases. (2) A pre-established and preset series of functions, maneuvers or operations: e.g., roll program, tilt over, gain change, etc.

Two examples are: (a) In missile guidance, the planned flight path events to be followed by the missile. The program includes all critical events which the ideal missile must accomplish to hit the target. It is the master plan according to which the missile functions. The programmer is a preset control used to time and sequence all internal events. (b) In computers, the program is the set of instructions introduced into the computer to guide its logic and sequence its operations for the solution of a particular problem.

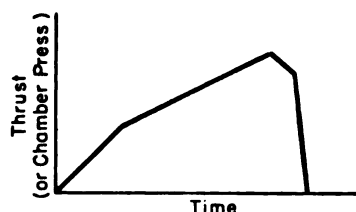
PROGRAM ANGLE. The angle between the vertical and the axis of a missile as measured in the flight plane.

PROGRAM DEVICE (PROGRAMMER). In missile guidance, the automatic device which accomplishes the **program**. It may be a simple clockwork or a complicated electro-mechanical circuit. The V-2 used a clock-

work type of programmer. This device accomplished the following: (1) Pitched and tilted the missile to follow the optimum trajectory. (2) Acted as a chronometer to control all missile operations which were functions of time. (3) Established the flight path and regulated all internal operations. (4) Introduced additional information into the guidance system as needed (e.g., changed gain factors, armed the warhead, etc.).

PROGRAMMER. Program device.

PROGRESSIVE BURNING. In rocket propulsion, a term meaning that the chamber pressure of the motor increases with time of burning. It is the opposite of **regressive burning**. It is usual in motor design to assume a constant chamber pressure, but in practice such constancy is not achieved. In progressive burning, thrust and chamber pressure increase with time. (See figure.)



Progressive burning in a rocket.

PROJECT. In military development work, a distinct unit of development effort which is of sufficient importance to warrant appropriate review at all Department of Defense levels. It is an undertaking to develop an assembly, accessory, attachment, end item, or principal component thereof or to explore a field of knowledge in search of scientific information.

PROJECT DISCOVERER. A U.S. project for firing heavy satellites into space, beginning in 1959.

PROJECT SCORE. A United States satellite launched successfully on December 18, 1958 under U.S. Air Force sponsorship. The satellite weighed some 8750 lbs., of which 150 lbs. was payload in the form of instruments and a communication relay station. A Christmas message of world peace from President Eisenhower was transmitted to the satellite. The message was internally recorded and periodically retransmitted to various nations of the earth. The Atlas Intercontinental Ballistic Missile, less its boosters, comprised the actual

satellite. It was 85 feet long and 10 feet in diameter. The orbit was 800 miles at **apogee** and 100 miles at **perigee**.

PROJECTILE. (1) An object, especially a missile, projected by an applied exterior force and continuing in motion by virtue of its own inertia, as a bullet, bomb, shell, or grenade. (2) Also applied to rockets, especially **rocket missiles**, and to **guided missiles**. (See **rocket projectile**.) The extension of meaning in sense 2 has been gradual and unobserved by many writers. In the process, the term has lost sharpness, for certain guided missiles, especially those of the winged variety, are not projected by an exterior force, and their continuing motion is by self-generated thrust.

PROJECTILE MOTION. Neglecting resistance of the air and considering a projectile describing plane curvilinear motion in the shape of a parabola, the following parametric equations apply: (See figure).

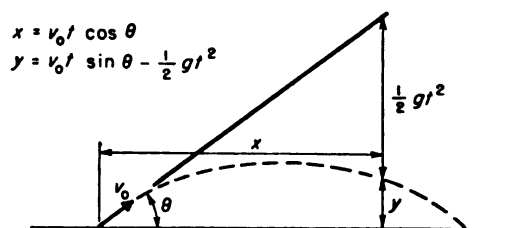
$$x = v_0 t \cos \theta$$

$$y = v_0 t \sin \theta - \frac{1}{2} g t^2$$

or

$$y = x \tan \theta - g x^2 / 2 v^2 \cos^2 \theta,$$

where x is the range, y is the altitude, v is the velocity, θ is the angle of velocity vector above the coordinate reference plane, g is the gravitational acceleration and t is the time.



Projectile trajectory in *vacuo*.

PROJECTION. (1) Any of various methods for representing the surface of the earth or the celestial sphere upon a plane surface. (2) A map or chart made by any one of such methods.

PROMINENCES. Prominences are regions of the solar **chromosphere** which, for some unexplained reason, extend out to a considerable height from the normal upper surface of this region of the solar atmosphere. In common with the chromosphere the prominences usually appear with a brilliant scarlet color. Up to the middle of the 19th century promi-

nences could be observed only during a total **eclipse** of the sun. In 1868 Lockyer and Janssen discovered a method for observing these interesting phenomena at any time. A high dispersion spectroscopic will spread out, and hence dilute greatly, the continuous spectrum of the sun. The prominences, however, shine by means of hot hydrogen and calcium, elements which have strong isolated bright lines which will appear strongly against the dispersed sunlight. By setting the view telescope of the spectroscopic to observe any of these strong lines, usually the red line of hydrogen, the slit of the instrument may be set tangent to the limb of the sun and widened until the entire prominence may be observed.

Prominences are of six chief classes: active, eruptive, sunspot, coronal, tornado, and quiescent. The quiescent prominences bear some resemblance to clouds in our own atmosphere, but are very large and extend out frequently as much as 50,000 miles from the sun. Eruptive prominences are smaller than the quiescent ones, but extend out from the sun to much greater distances, frequently more than 500,000 miles, and are found to have high velocity, as great as 200 miles per sec., out from the sun. Both the quiescent and eruptive prominences contain hydrogen, calcium, and helium, but the eruptive prominences are also found to contain iron, magnesium, and other elements apparently carried up from the lower atmosphere of the sun.

There is no adequate explanation for the enormous force necessary to project matter out from the sun with such high velocity against the strong surface gravity. The number of prominences is directly correlated with the number of **sun spots**. The quiescent prominences may appear at any portion of the sun's disk, but the eruptive type are limited to the latitude zones in which the sun spots are found, and frequently rise from the vicinity of active spots.

PROPAGATION ANOMALIES. Irregularities introduced into an electromagnetic or other sensing device by discontinuities in the medium of propagation.

PROPAGATION CONSTANT. A transmission characteristic of a line or medium, which indicates the effect of the line on the wave being transmitted along the line. It is a complex quantity having a real term, the attenuation constant, and an imaginary term, the

wavelength or phase constant. The attenuation constant is a measure of the loss in signal strength as the wave travels along a matched line, while the wavelength constant is a measure of the phase shift which it undergoes. These relations may be expressed by the following equations:

$$r = a + jB, \quad E_r = E_s e^{-(a+jB)l}$$

$$|E_r| = |E_s| e^{-al}$$

$$|I_r| = |I_s| e^{-al}$$

$$\text{Phase displacement} = Bl$$

where r is the propagation constant, a the attenuation constant, B the wavelength constant, l the line length, E_r the received voltage, E_s the sending end voltage and I the corresponding currents. Because of the attenuation on lines used for communication purposes it is necessary to insert **amplifiers** or repeaters at intervals to build the signal back to suitable levels. For sound work the phase shift is usually not important but for television and picture transmission it is extremely important and necessitates correcting circuits.

PROPANE. A hydrocarbon fuel (C_3H_8) having a boiling point of $-44^\circ F$, freezing point $-308^\circ F$, specific gravity of 0.508, and coefficient of heat at constant pressure of 0.365.

PROPELLANT(S). (1) Agents used for consumption or combustion in a rocket and from which the rocket derives its thrust, such as a fuel, oxidant, additive, catalyst, or any compound or mixture of these; specifically, a fuel, oxidant, or a combination of fuel and oxidant used in propelling a rocket. (2) Also rocket propellants. All of the individual agents, especially fuel and oxidant, taken collectively, used in a rocket for its propulsion. When the oxidant and fuel are combined in a single substance, this substance is termed a "monopropellant," otherwise it is a "bi-propellant."

Solid Propellants. Solid propellants have certain advantages over liquid types in that they employ less plumbing in the motor; are simpler to maintain; can be stored in a "ready-to-fire" condition enabling rapid employment, and are much simpler to handle. They are also not susceptible to in-flight sloshing as are liquid propellants. Therefore, no weight needs to be wasted on anti-sloshing devices inside fuel cells. Solid propellants have

certain disadvantages, however: they are sensitive to temperature changes and are more costly than liquid types; their exhaust is generally smokier; heavier combustion chambers are required; intermittent operation is difficult, overall performance is lower than for liquid types, and the aerodynamic center of gravity unavoidably shifts during in-flight burning.

Since World War II research effort has been applied to eliminate the unfavorable aspects of solid propellants in order to produce solid types with the following desirable qualities: high specific impulse, high density, predictable and reproducible performance, wide temperature limits, good storage stability, high mechanical strength, smokeless, non-corrosive, non-toxic, non-hygroscopic, easy, safe and inexpensive to make. Today the research effort has produced solid propellant types of high efficiency. Certain smaller rockets with limited objective missions have been produced in solid propellant types to supplant older liquid rockets.

The following are examples of materials used for solid propellant rockets: diglycol, diethylene glycoldinitrate, diglycol-dinitrate, diphenylamine plus ethyl centralite (JPT), the ballistites, the GALCIT propellants (rubber base), the NDRC propellants, DEGN, the asphalt-oils, nitroglycerins, rubber-perchlorates, asphalt-perchlorates, asphalt-potassium perchlorates, black powder with ammonium nitrate, and other combinations recently developed.

Liquid Propellants. Liquid propellant rockets appear to be the best for large, long-range types of vehicles. Their use permits the transport of a much lighter (empty) piece of equipment which can be fueled on the launching site after handling as an empty shell. The liquid types can be cut-off in flight to a more precise velocity in order to obtain good accuracy, or they may be operated intermittently.

Liquid propellant rockets can be of either the monopropellant or bi-propellant types. Monopropellants include hydrogen peroxide which reacts alone or with a catalyst to produce the propulsive force. Generally two components of propellants are used: the **fuel** and the **oxidizer**. These materials are stored in separate fuel cells and are mixed in the correct proportions in the injection devices which supply the combustion chamber. Gen-

erally one or both of the propellants are liquefied gases.

Typical fuels used in liquid propellant rockets are: acetylene, alcohols, aluminum borohydride, ammonia, ammonia plus methyl alcohol, aniline, benzene, butyl mercaptan, diborane, diethylenetriamine, diethylene triamine plus methylamine, ethane, ethyl alcohol, ethylamine, ethylene, ethylene diamine, ethylene oxide, ethyl alcohol plus methyl alcohol, ethyl nitrate, ethyl silicate, furfuryl alcohol, gasoline, heptane, hydrazine, hydrogen, isopropyl alcohol, JP-3, JP-4, kerosene, lithium, lithium hydride, methane, methyl acetylene, methylal, methyl alcohol, methyl alcohol plus hydrazine hydrate, methylamine, methyl cyclopentane, nitroethane, nitromethane, nitropropane, n-octane, n-propyl nitrate, o-toluidine, polyethylene, propylene oxide, propylene oxide plus ethylene oxide, triethylamine, triethylamine plus orthotoluidine, triethyl trithiophosphite, trimethyl trithiophosphite, turpentine, unsymmetrical dimethyl hydrazine, unsymmetrical dimethyl hydramine, xylidene, and other materials having light molecular structure and high energy content when burned with an oxidizer. Some later fuels make use of the atomic disassociation for additional energy release upon recombination. The so-called "high energy" fuels make use of the heat content of non-hydrocarbon type materials such as boron, lithium, and other materials.

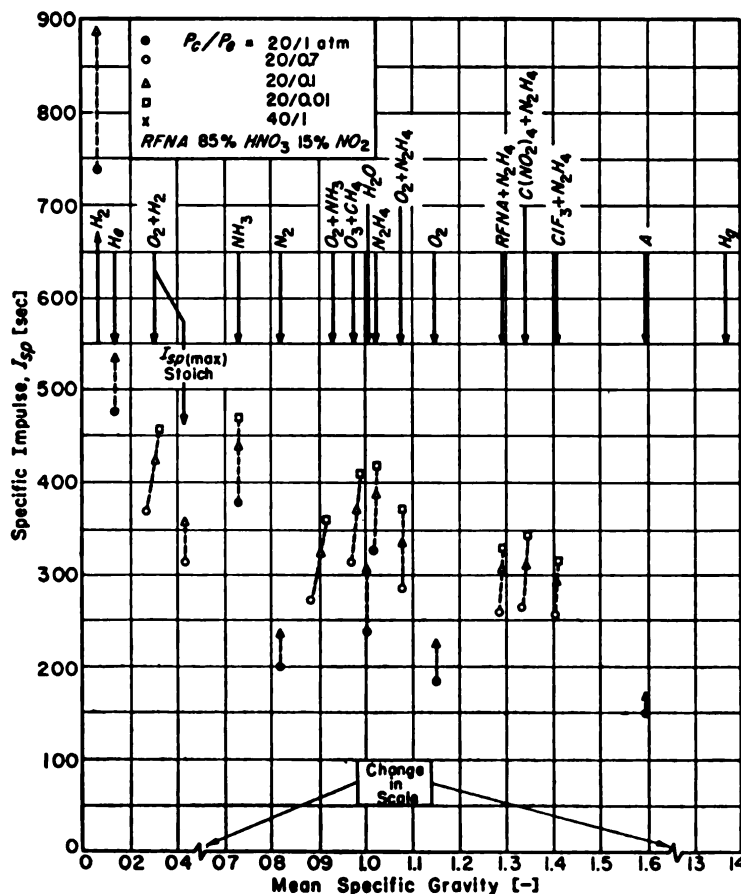
Typical oxidizers used in rocket motors are: chlorine heptoxide plus tetroxide, chlorine trifluoride, fluorine, fluorine plus nitrogen trifluoride, hydrogen peroxide, hydrogen peroxide plus ammonium nitrate plus water, nitric acid, nitrogen tetroxide, ON7030 (70% nitrogen tetroxide plus 30% nitric oxide), oxygen, oxygen plus ozone, oxygen difluoride, ozine, red fuming nitric acid (with 6.5%, 15% and 22% NO_2), tetranitromethane, white fuming nitric acid, and other materials containing a high percentage of available oxygen.

PROPELLANTS, ADVANCED. Since the limiting values for chemical propellants are of the order of 4,000°K (7,200°F), 68 atmospheres pressure and 450 lb.sec./lb. specific impulse, the future of space flight is closely dependent upon propellants that yield far higher energy and impulse that are available from the chemical propellants. Recombination propellants use atoms, free radicals or

molecular fragments as their energy sources. The principle involved in the use of these propellants is to store energy in the form of dissociation energy of the molecules into atoms or radicals, which becomes available when they recombine, and so produces great energies and high velocities in the combustion chamber-exhaust nozzle system. For example, dissociated hydrogen (atomic hydrogen) is a very energetic source of fuel. Molecular dissociation energy can be utilized either by storing the molecular fragments in their dissociated form, or by producing the fragments as they are needed and allowing them to recombine immediately, as is done in an electric arc propulsion system. In the first method one faces severe problems of storage, handling and pumping. Free radical propulsion is therefore still in the research stage, and it may take a long time to yield practical results for terrestrial rocket vehicles. For space vehicles, free radical storage is, in principle, much easier to accomplish, because of the very low temperatures at which the ma-

terial can be kept if properly shielded from radiation. The arc method is more straightforward but the overall efficiency of this system is very low, so that arc propulsion poses severe energy and energy-disposal (cooling) problems. Propulsion by recombination, nevertheless, has very attractive specific impulse characteristics. The recombination to molecular hydrogen releases 93,000 Btu/lb., and yields temperatures above 10,000°F.

The use of atomic reactors for heating working fluids provides a practically unlimited energy supply (about 40,000 times the dissociation energy of hydrogen). However, the combustion process is now replaced by a heat transfer process, and the efficiency of energy conversion is very low. A reactor of low critical mass and high operating temperature must be developed. The considerable weight requirements for shielding the crew, and the probable restriction of the use of such power plants to upper stages, in order to avoid launching site contamination, are distinct disadvantages of this propulsion system. The



Specific impulse vs. density of propulsion fluids.

obtainable specific impulse depends on the working fluid to which the heat is transferred. For an initial temperature of 3,000°K (about 5,000°F) a variety of working fluids is compared with a number of chemical propellants in the graph of Specific Impulses vs. Density of Propulsion Fluids. Altogether this temperature is very high for reactor operation, and it can be seen that aside from hydrogen, helium and ammonia, the working fluids do not yield a superior specific impulse. For space vehicles, however, a nuclear-heated hydrogen propulsion system would be of great advantage over chemical systems.

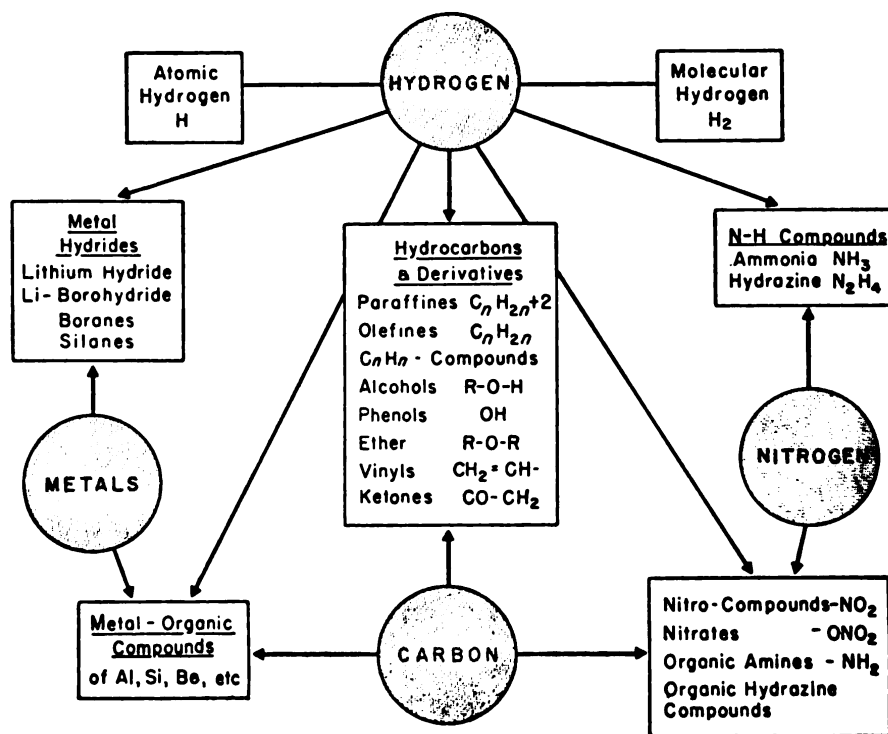
These two propulsion methods alone in the spectrum of advanced propulsion system can produce thrust-to-weight ratios which are adequate for takeoff from the surface of a celestial body such as the earth, moon or one of the planets.

PROPELLANT, AUTO-IGNITING. Any propellant that ignites at room temperature, with adequately small time delay.

PROPELLANT(S), CHEMICAL. As shown in the accompanying figure, the basic components of chemical fuels are hydrogen, carbon,

nitrogen and metals. Nitrogen does not contribute energy. Very high specific impulse values are obtained with hydrogen and hydrogen-rich compounds, such as ammonia, hydrazine, methane and some metal hydrides. Carbon-rich fuels are inferior, because of higher molecular weight of the combustion products. Future emphasis will therefore probably be directed toward the hydrogen-rich fuels. Unfortunately, these fuels usually have low density (the exception is hydrazine). Combustion of metals yields increased heat release, resulting in very high combustion temperatures (7,000 to 13,000°F). With hydrogen, even with a hydrogen-nitrogen gas mixture from decomposed ammonia or hydrazine, metal combustion would produce a very high specific impulse. In the case of the metals in practice, most of the energy is absorbed by vaporizing the metal oxides so that the specific impulse values are not higher than those obtained with some other propellants at lower temperatures. The use of metals, therefore, does not necessarily increase the concentration of useful energy in the vehicle.

PROPELLANT, COMPOSITE. A propellant in which oxidant and reductant occur as separate, distinct entities.



Chemical propellants.

PROPELLANT, DOUBLE-BASE. A propellant consisting of nitrocellulose and nitroglycerin with the addition of certain stabilizers.

PROPELLANT, DOUBLE-BASE POWDER. A solid rocket propellant consisting of gelatinized colloidal mixtures of nitroglycerin and nitrocellulose, to which certain stabilizers have been added.

PROPELLANT, HETEROGENEOUS. A propellant in which oxidant and reductant occur as separate, distinct entities. (See **propellant, composite**.)

PROPELLANT, HOMOGENEOUS. A solid propellant in which the oxidant and reductant (or a mixture of monopropellant materials) occur as a single, or colloidal entity; often termed colloidal. An example of this type of propellant is ballistite or cordite where nitrocellulose is colloidized with another monopropellant such as nitroglycerin and other additives to provide the proper combustion characteristics and physical properties.

PROPELLANT LOADING RATIO (y_k). (1) The ratio of propellant loaded on a missile to the gross weight of the missile. (2) The ratio of the propellant loaded on a missile to the dry weight of the missile. (Note that these commonly used definitions are quite different.)

PROPELLANT, RESTRICTED. A propellant system in which combustion takes place perpendicular to the longitudinal axis of the grain ("cigarette" fashion). It is termed end burner (or end burning grain).

PROPELLANT, ROCKET ENGINE. A material, consisting of fuel and oxidizer, either separate or together, liquid or solid, in a mixture or compound which, when suitably ignited, changes into a large volume of hot gases which, upon ejection through a nozzle, impart momentum to a rocket or missile.

PROPELLANT SELECTION. The data and considerations regarding propellant selection appear in figure on Page 476. A great number of parameters are involved, specific impulse and density being particularly significant from the viewpoint of overall performance. While there is no single optimum propellant, with increasing performance level and increasing vehicle size the emphasis shifts from heavier

propellant combinations with lower specific impulse toward lighter propellants with higher specific impulse. Oxygen-hydrogen or fluorine-hydrogen, ammonia, helium and hydrogen appears most promising for operations in cis-lunar and interplanetary space if chemical propellants or working fluids are used, while comparatively heavier propellants are indicated for the streamlined, multi-stage vehicles starting from the surface. Staging is the most effective means of compensating for the energy deficiency of propellants and working fluids. The purpose of staging is to minimize the amount of dry weight accelerated during powered flight. A variety of staging methods are conceivable and have been considered, such as arrangement of the stages in series (tandem), in parallel (cluster), telescopic staging, a mixed tandem and parallel arrangement, as well as jettisoning of components such as engines and tanks.

PROPELLANT, SINGLE-BASE. A nitrocellulose propellant.

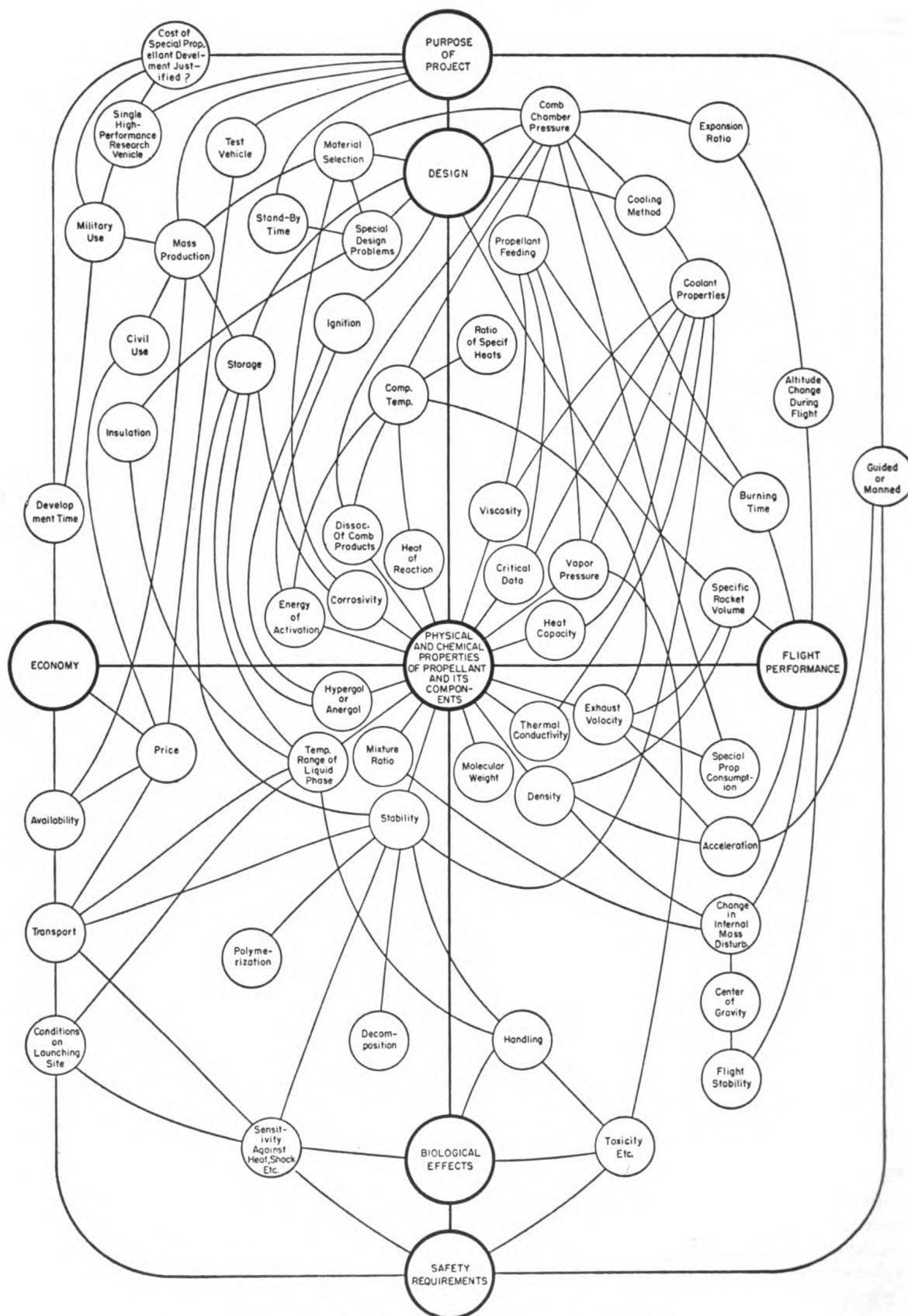
PROPELLANT, TRAPPED. Trapped propellant.

PROPELLANT, UNRESTRICTED. A propellant grain wherein combustion takes place on more than one planar surface.

PROPELLANT UTILIZATION SYSTEM. A measuring system used in long-range rockets to insure that the fuel and oxidizer are consumed in the proper ratio so that a minimum of residual propellant remains at the end of powered flight.

PROPELLANT-WEIGHT RATIO. The ratio of weight of propellant to takeoff weight of missile. This ratio is a measure of the overall efficiency of the combination of missile configuration and missile power plant. The higher this ratio, the more efficient is the design. However, this consideration is more important for missile using conventional fuels than it is by those operating on the higher energy sources, such as exotic fuels, nuclear energy, free radicals or other possible sources of energy. (See **mass ratio**.)

PROPER FUZE FUNCTION. A fuze function which occurs within a standard deviation of plus or minus three of the normal distribution for fuze function



Concept of parameter connections in propellant selection.

PROPER MOTION. The individual motion of a star relative to the other stars is known as the proper motion of the star. Up to the early part of the 18th century the belief was current that the stars were all fixed on a sphere commonly known as the **celestial sphere**. Since this sphere was apparently rotating about the earth and possessed other motions such as **precession** and **nutation**, all of the stars had certain motions in common. In 1718, Edmund Halley, while reducing his observations of the positions of the stars, noted that the positions which he obtained for Sirius and Arcturus differed in position relative to the other stars from the positions given by Ptolemy. Since the differences were greater than could be ascribed to errors in observation, Halley concluded that these two stars were actually not fixed on the celestial sphere but were in motion.

Since Halley's time, many stars have been observed to have proper motion and many long programs are at present under way to study these motions. The standard method of procedure is to compare positions of the stars at two epochs as widely separated as possible. Visual observations made with extreme precision with a **meridian circle** may be used for this purpose, but the photographic methods are far more fruitful since a large number of star positions may be obtained on a single plate. The longer the interval of time between the observations, the more accurate is the determination of the proper motion, and also the smaller the proper motion which can be detected.

Proper motion can only be determined in angular units, and the results are usually expressed in terms of seconds of arc per year. In case the **stellar parallax** of the star is known the velocity in linear units may be computed in accordance with methods discussed under **space velocity** of a star. The largest known proper motion is $10''.25$ per year and was found by Barnard for a tenth magnitude star. Such a star would require about 200 years to change its position by an amount equal to the apparent diameter of the moon. There are only about 50 stars known to have proper motions greater than $2''$ per year and not more than 1000 with values greater than $\frac{1}{2}''$ per year. Hence, we should not expect the constellation figures to have altered appreciably in the 5000 years since they were first described.

PROP-JET. Turboprop.

PROPORTIONAL CONTROL. Radio control of an aircraft, missile, etc., in which control surface deflection is proportional to the movement of the remote controls. (Cf. **flicker control**.)

PROPORTIONAL NAVIGATION. Navigation, proportional.

PROPULSION BRANCH. The powered portion of flight path of a missile or rocket. It is the trajectory from **takeoff** to **cut-off**.

PROPULSION, JET. Any method for propelling a body which employs as its propulsive thrust the reaction force produced by the discharge of matter from the propelled body; the discharged matter being in the form of a jet of fluid. Two general types of jet propulsion are utilized:

- (a) The jet consisting of highly heated, compressed, atmospheric air, admixed with the products of the combustion produced by burning a fuel in the air; the thermal energy of the fuel being employed to raise the air temperature to the desired value. A jet of this type is termed a *thermal jet*. (See **thermal jet engine**.)
- (b) The jet formed by generating large quantities of high-pressure, high-temperature gases by means of a chemical reaction which does not utilize atmospheric air. A gaseous jet produced in this manner is termed a *rocket jet*. (See **rocket engine**.)

PROPULSION, ROCKET. Rocket propulsion.

PROPULSION SYSTEM. The entire system required to propel a **missile**, including the engine, accessories such as pumps and turbines, pressurization system, tankage and all related equipment.

PROSIGN. In communications, a single letter, character, word or combination of these used before transmitted messages to identify station transmitting, prescribe routing, or otherwise assist in the handling of the message.

PROTACTINIUM. Radioactive element. Symbol Pa. Atomic number 91.

PROTON. (1) A positively charged elementary particle of mass number 1 and charge equal in magnitude to the electronic charge e . It is one of the constituents of every nucleus; the number of protons in the nucleus of each atom of an element is given by the atomic number Z of the element. Other properties of the proton are: rest mass, 1.67×10^{-24} gm, or 1.0075 amu; magnetic moment, 2.79245 nuclear magnetons, or 1.52×10^{-3} dyne cm gauss $^{-1}$; spin quantum number, $\frac{1}{2}$; described by Fermi-Dirac statistics. (2) The nucleus of an atom of hydrogen of mass number 1. (3) The negative proton is discussed under **anti-proton**.

PROTON-PROTON CHAIN. A series of **thermonuclear reactions** initiated by a reaction between two protons, namely $H^1 + H^1 \rightarrow H^2 + \beta + \nu$, that provides the energy of some stars. The subsequent reactions are presumed to be $H^2 + H^1 \rightarrow He^3 + \nu$, followed by $He^3 + He^3 \rightarrow He^4 + H^1 + H^1$. The net result is the same as in the **carbon cycle**, namely, the synthesis of four hydrogen atoms into one helium atom, with the liberation of the mass difference as energy. It is thought that the proton-proton cycle is more important than the carbon cycle in the cooler stars, and that the reverse is true in the hotter stars. Both cycles are believed to be important in the sun.

PROTOTYPE. A model (of a guided missile or other equipment) that is suitable for complete evaluation of form, design, and performance. A prototype model utilizes approved parts and is representative of the final equipment. It follows an experimental model and precedes the production model.

PROTOTYPE EQUIPMENT. New equipment developed and produced to evaluate in service its suitability for establishing standards for production models.

PROXIMITY DETECTOR. Detector, proximity.

PROXIMITY FUZE. Fuze, proximity.

PSEUDOADIABAT. A diagonal line on a meteorological or synoptic chart showing graphically the cooling which theoretically takes place when a moisture-saturated parcel or air rises vertically, or the heating which

theoretically takes place when such a parcel of air descends vertically.

PSEUDOADIABATIC CHART. A chart containing a series of diagonal lines, called "pseudoadiabats," showing graphically the cooling or heating which theoretically takes place in a series of ascending or descending parcels of moisture-saturated air.

PSEUDO-INTEGRATION. A means of determining the occurrence of a given minimum value of the time integral of acceleration; often used as an S & A actuator.

PSYCHROMETER. Hygrometer.

Pt. Platinum.

PTM. Modulation, pulse time.

Pu. Plutonium.

PU SYSTEM. Propellant utilization system. In a missile, a control automation to regulate the mixture ratio or flow rates to a rocket motor. It is similar to the carburetor and throttle system on an automobile (less the human link). The term propellant utilization can refer to both the manner in which the propellant mixtures are controlled during the motor burning and also the efficiency of the missile system in consuming propellants, so as to reduce the amount of residual propellants required to be carried aboard in order to insure sufficient reserve to account for non-standard performance of the power plant.

PULSE. (1) A variation of a quantity whose value is normally constant; this variation is characterized by a rise and decay, and has a finite duration. (2) A waveform whose duration is short compared to the time-scale of interest, and whose initial and final values are the same. The word "pulse" normally refers to a variation in time; when the variation is in some other dimension, it shall be so specified, such as "space pulse." This definition is broad so that it covers almost any transient phenomenon. The only features common to all pulses are rise, finite duration, and decay. It is necessary that the rise, duration, and decay be of a quantity that is constant (not necessarily zero) for some time before the pulse and has the same constant value for some time afterwards. The quantity has a normally constant value and is perturbed dur-

ing the pulse. No relative time scale can be assigned.

One type of pulse is the high power, short duration output of a pulse radar system; e.g., a sinusoidal voltage of VHF to EHF (100 to 30,000 mc, 3 m to 1 cm) is transmitted for a period of, typically, 1 microsecond.

PULSE ALTIMETER. A radio altimeter that sends out brief surges, or pulses, of radio-frequency energy, the time distance between the transmitted and reflected pulses being used to determine altitude.

PULSE AMPLIFIER. An amplifier, designed specifically to amplify the intermittent signals of a nuclear detector, incorporating appropriate pulse-shaping characteristics.

PULSE AMPLITUDE MODULATION (PAM). Modulation in which the modulating wave is caused to amplitude-modulate a pulse carrier.

PULSE AMPLITUDE, PEAK. The maximum absolute peak value of the pulse, excluding those portions considered to be unwanted, such as spikes. Where such exclusions are made, it is desirable that the amplitude chosen be illustrated pictorially.

PULSE AMPLITUDE, RMS (EFFECTIVE). The square root of the average of the square of the instantaneous amplitude, taken over the pulse duration.

PULSE CARRIER. A carrier consisting of a series of pulses.

PULSE CARRIER, CREST FACTOR OF. The ratio of the peak pulse amplitude (see pulse amplitude, peak) to the root-mean-square amplitude. (See pulse amplitude, rms.)

PULSE CODE. (1) The modulation imposed on a pulse train to convey information. (2) Loosely, a code consisting of pulses, such as Morse code, Baudot code, Binary code.

PULSE-CODE (PCM) MODULATION. Modulation which involves a pulse code. This is a generic term, and additional specification is required for a specific purpose.

PULSE DECAY TIME. The interval between the instants at which the instantaneous amplitude last reaches specified upper and

lower limits, namely, 90 per cent and 10 per cent of the peak-pulse amplitude (see pulse amplitude, peak) unless otherwise stated.

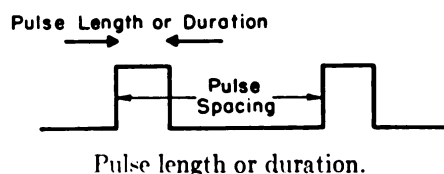
PULSE DURATION. The duration in time of a pulse, especially of a pulsed electromagnetic wave.

PULSE-DURATION OR PDM MODULATION. Pulse-time modulation in which the value of each instantaneous sample of the modulating wave is caused to modulate the duration of a pulse. The terms "pulse-width modulation" and "pulse-length modulation" also have been used to designate this system of modulation. In pulse-duration modulation, the modulating wave may vary the time of occurrence of the leading edge, the trailing edge, or both edges of the pulse.

PULSE-FREQUENCY MODULATION (PFM). A form of pulse time modulation (see pulse time modulation) in which the pulse repetition rate is the characteristic varied. A more precise term for "pulse frequency modulation" would be "pulse repetition-rate modulation."

PULSE, LEADING EDGE. The major portion of the rise of a pulse of electrical energy.

PULSE LENGTH. The time duration of the transmission of a pulse of energy, usually measured in microseconds or in the equivalent distance in yards, miles, etc., represented by the pulse signal on a radar-scope. (Short pulses of from 0.1 to 1 microsecond are usual for accurate radar work; longer pulses up to about 10 microseconds are used for less accurate work at greater ranges.) (See figure.)



PULSE-LENGTH ERROR. An error caused by pulse length, which makes certain targets appear longer or thicker than they actually are in the direction of the radar beam.

PULSE MODULATION. (1) Modulation of a carrier by a pulse train. In this sense, the term is used to describe the process of generating carrier-frequency pulses. (2) Mod-

ulation of one or more characteristics of a pulse carrier. In this sense, the term is used to describe methods of transmitting information on a pulse carrier. (See **quantized pulse modulation**.)

PULSE-POSITION OR PPM MODULATION. Pulse-time modulation (see **pulse-time modulation**) in which the value of each instantaneous sample of a **modulating wave** is caused to modulate the position in time of a **pulse**.

PULSE REPEATER (TRANSPONDER). A device used for receiving **pulses** from one circuit and transmitting corresponding pulses into another circuit. It may also change the frequency and waveforms of the pulses, and perform other functions.

PULSE, RADAR. Radar pulse.

PULSE, RADIO-FREQUENCY. A radio-frequency carrier, amplitude-modulated by a pulse. The amplitude of the modulated carrier is zero before and after the pulse. Coherence of the carrier (with itself) is not implied.

PULSE REPETITION FREQUENCY. The pulse repetition rate of a periodic pulse train.

PULSE REPETITION RATE. The average number of pulses per unit of time.

PULSE RISE TIME. The interval between the instants at which the instantaneous amplitude first reaches specified lower and upper limits, namely, 10 per cent and 90 per cent of the peak-pulse amplitude (see **pulse amplitude, peak**), unless otherwise stated.

PULSE SHAPER. A **transducer** used for changing one or more characteristics of a **pulse**. This term includes pulse regenerators.

PULSE SPACING. The time duration (usually expressed in microseconds) between the corresponding **pulse times** of two consecutive pulses. (See **pulse length**.)

PULSE SPIKE. An unwanted **pulse** of relatively short duration superimposed on the main pulse. This term came into wide use in **radar** to define the first part of the pulse fed through a **TR tube**. This portion contains most of the pulse energy, has a duration about 10^{-3} that of the rest of the pulse, and

an amplitude up to 10^6 to 10^9 times that of the rest of the pulse. Seen on a cathode-ray tube, it looks like a spike sticking up from the pulse. By extension, the term has come to be applied to any unwanted pulse of relatively short duration, superimposed on the wanted pulse.

PULSE STRETCHER. A special video detector which converts a train of video pulses into a d-c voltage upon which is superimposed an a-c signal proportional to the modulation envelope of the pulse train. The a-c component contains the angle information. The d-c component is a function of average pulse amplitude and is used to control the receiver gain.

PULSE TIME, LEADING-EDGE. The time at which the instantaneous amplitude first reaches a stated fraction of the peak pulse amplitude.

PULSE-TIME OR PTM MODULATION. **Modulation** in which the values of instantaneous samples of the **modulating wave** are caused to modulate the time of occurrence of some characteristic of a **pulse carrier**. Pulse-duration modulation and pulse-position modulation are particular forms of pulse-time modulation.

PULSE TIME, TRAILING-EDGE. The time at which the instantaneous amplitude of a pulse of electrical energy last reaches a stated fraction of the peak pulse amplitude.

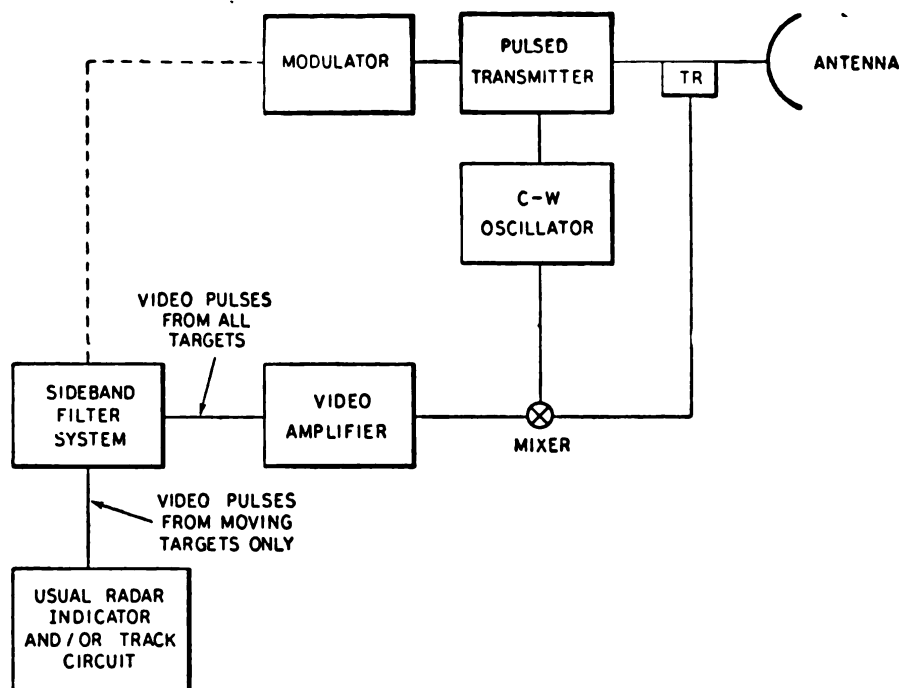
PULSE TRAIN. A series of pulses in digital representation of data.

PULSE WIDTH (LENGTH, DURATION). The time duration of any single electrical wave of an impulse type measured at a specific level. (In practice, the base pulse width is measured at ten percent of normal amplitude and the peak pulse width is measured at ninety percent of normal amplitude.)

PULSE WIDTH MODULATION. Pulse duration modulation; **telemetry**.

PULSED ALTIMETER. A radar altimeter that emits pulses of radio-frequency energy.

PULSED DOPPLER RADAR. A radar system making use of the translation of speed variations of a reflecting body into frequency



Pulsed Doppler radar.

variations of the radar pulses reflected by the body. (See figure.)

PULSEJET. A compressorless jet-propulsion device which produces thrust intermittently, with an operating frequency determined by the acoustic resonance of the engine. It consists of a pulsating or intermittent inlet-valve system, a combustion chamber, and a discharge nozzle. Owing to the partial vacuum created for a short time in each cycle by the pulsating nature of the combustion and exhaust, this device can take in air and produce thrust even under static conditions.

PULSEJET ENGINE. A type of compressorless jet engine in which combustion takes place intermittently, producing thrust by a series of explosions, commonly occurring at the approximate resonance frequency of the engine.

In the earlier, and commoner, type of pulsejet (as used, e.g., in the German V-1 flying bomb of WW II), air is admitted into the combustion chamber by a set of alternately opening and closing flaps, vanes or valves; later types have been designed to operate intermittently without the use of moving parts. (The latter type is sometimes called specifically a "valveless pulsejet.") All types are capable of static operation. Also called "aer-

opulse engine," "aeroresonator," "intermittent-jet engine," "resojet," etc. (See **ramjet engine**; **resojet engine**.)

PUMP DRIVE ASSEMBLY (PDA). An assembly used in liquid rocket propulsion systems consisting of the turbine, propellant pumps, gear boxes, power takeoffs and housing.

PURSUIT COURSE. A homing guidance system in which the missile is directed along a flight path whose tangent coincides with the **line-of-sight** from missile seeker to target or deviates from it by a predetermined fixed angle. There are two pursuit courses in guidance theory: the *pure pursuit course* in which the missile velocity vector is always directed toward the instantaneous target position, and the *deviated pursuit course* in which the angle between the missile velocity vector and the line-of-sight from the missile to the target is fixed. If the fixed lead angle is zero, the pure pursuit course results. (See Figure on Page 482.)

PUSHER. A large solid-propellant booster-type rocket developed by the Rocket Fuels Division of Phillips Petroleum Company. Its propellant contains ammonium nitrate, synthetic rubber and carbon black. It is used for **RATO** work.

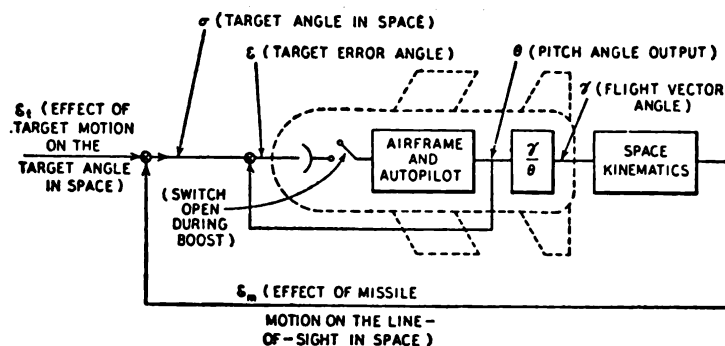


Diagram of a Pursuit Navigation Loop.

PUSH-PULL OSCILLATOR. A vacuum-tube oscillator containing two tubes, or a double-section tube connected in a phase relation similar to that of a push-pull amplifier.

PUSH-PULL PARALLEL CIRCUIT. A vacuum tube circuit consisting of four tubes (or two double-section tubes) which are arranged in pairs, connected with their grids and plates in parallel, and then treated as two single tubes connected in push-pull. The circuit is used chiefly in high-powered amplifiers.

PUSH-PULL TRANSFORMER. An iron-core audio-frequency transformer designed to use in a push-pull amplifier circuit. If it is the input transformer, it has a center-tapped secondary winding; if it is the output transformer, it has a center-tapped primary winding.

PUSHOVER. (1) The programmed tilting of a flight path from the vertical toward the horizontal. Many heavy ballistic missiles take off vertically and ascend for a number of seconds straight upward over the launcher without any down-range movement until the pushover altitude is reached. There the flight path is changed to begin the downrange tilt. (2) A more or less sudden movement downward in pitch, as at the dump point of an aerodynamic missile. (3) The code name for a series of tests conducted by the U.S. Navy to determine the effect on ships of a missile falling over after ignition, but before appreciable separation was obtained. The purpose was to give planning factors of damage likely to result from shipboard missile disasters.

PUSH-PUSH CIRCUIT. A two-tube amplifier circuit in which the grid of one tube

operates 180° out of phase with the grid of the other tube, but the plates are connected. It is noted for fairly high efficiency when used for frequency doubling in radio frequency power amplifiers.

PWM. Pulse Width Modulation. (See **telemetering**, **pulse width modulation**; **telemetering**, **pulse duration modulation**.)

PYRANOMETER. An instrument measuring radiation from sun or sky by its heating action upon two blackened metallic strips, as compared with the electric current which produces the same heating effect. Commonly the two blackened strips differ greatly in thickness, and hence the temperature rise on exposure to radiation is less in the thick strip than in the thin one.

PYRGEOMETER. An instrument measuring radiation from the earth's surface into space. It has both blackened and polished areas; the former cool more rapidly by radiation from them, and the heating electric current necessary to prevent this differential cooling measures the amount of radiation.

PYRHELIOMETER. An instrument for measuring the total intensity of solar radiation, both direct and scattered by the atmosphere.

PYROMETER. In earlier usage a pyrometer was a device for measuring high temperatures, but these instruments are now used also for temperatures in the same range as thermometers, and below the thermometric range. Four major types of pyrometer are the thermoelectric pyrometer (thermal or thermocouple), the resistance pyrometer, the optical pyrometer and the (total) radiation pyrometer.

PYROPHORIC FUEL. A fuel which ignites spontaneously in air; useful as a high-energy fuel for jet airplanes, and as a propellant for missiles. This fuel has the advantages of relatively low cost, high energy yield and avoidance of "flameout" in thin air. Its disadvantage is its destructiveness to living tissue, and its violent reaction with water or

other hydrogen-containing compounds. Examples are aluminum trimethyl and aluminum triethyl.

PYROTECHNIC. A mixture of oxidant and reductant designed to produce light or heat, or to perform some other non-propulsive function.

Q

Q. (1) A **figure of merit** of an energy-storing system equal to

$$2\pi \left(\frac{\text{average energy stored}}{\text{energy dissipated per half cycle}} \right),$$

which is equal to $\omega L/R$ for an inductor, where R is the equivalent series resistance. For a capacitor, Q is $1/\omega CR$, again the ratio of reactance to effective resistance. For a medium, Q is the ratio of **displacement current density** to **conduction current density**. The basic equation may also be expanded to include series and parallel resonant circuits, for which cases appropriate approximate equations may also be developed (see **sharpness of resonance**). (2) Quantity of heat, light, or energy (Q). (3) Electric charge (Q or q). (4) Heat entering system (q). (5) Moment of area (Q). (6) Electric quadrupole moment of atomic nucleus (Q). (7) Thermoelectric power (Q). (8) In aerodynamics, a letter symbol commonly used for dynamic pressure. It is given value by the equation:

$$q = \frac{1}{2}\rho v^2$$

Where q is the dynamic pressure, ρ is the density of the fluid, and v is the velocity of the body relative to the fluid flow. In control systems "q" is often spoken of as a parameter in itself. For example a "q"-switch might be a relay designed to make changes in the constants of the control equation during different phases of the missile's flight through the atmosphere. In the thin upper atmosphere, the "q" effect is less than at some lower altitudes for the same relative speed of the body, and therefore more control surface deflection might be necessary to achieve a given maneuver.

Q-5. The Lockheed Aircraft Company Mach 2 target drone powered by a Marquardt ramjet with rocket boost. Its dimensions are 39 feet in length, 7600 pounds in weight, and 10 feet in wingspan.

QA. Quality assurance.

QC. Quality control.

QOR. Qualitative operational requirement.

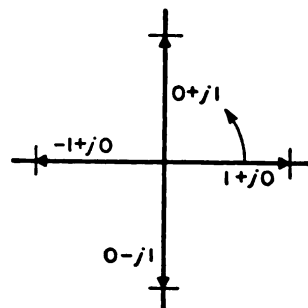
QPRI. Qualitative personnel requirements information.

Q-METER. A device for measuring the "Q" of circuits. (See **Q** (1).)

QUADRANT. (1) An instrument similar to a sextant, but constructed with its arc graduated in degrees for a fourth of a circle. Often called a "sextant." (2) An instrument with a scale graduated in ninety degrees, used in laying a gun or mortar for elevation; a **clinometer**. (3) The fourth part of something, as a quadrant in a radio range, or **sky-condition** observation.

QUADRANT ELEVATION. Elevation quadrant.

QUADRATURE. Displaced 90° in phase angle. This is expressed by use of the letter j , which may be considered as an operator producing a rotation of 90° counterclockwise. Since j equals the square root of minus one, the square of j equals minus one. Thus two such operations would result in rotation of 180° or from plus to minus. An additional rotation of 90° (total 270°) results in minus j . A unit vector rotating through its four principal positions is shown below.



Quadrature.

QUAIL (GAM-72). A U.S. Air Force research and development missile assigned to McDonnell Aircraft Corp. in 1957. It is an

air-launched decay to confuse enemy defenses. It is to be powered by General Electric; to be equipped with various countermeasures; and designed to be carried by B-47's and B-52's.

QUALIFIED COMPONENT. A component (part, assembly) which has successfully passed a set of predetermined performance and environmental tests.

QUALITATIVE OPERATIONAL REQUIREMENT (QOR). A formal statement of an essential operational need of a U.S. Air Force activity, including the broad characteristics of the item, system, technique needed to enable the Air Force to carry out its assigned mission more effectively.

QUALITATIVE PERSONNEL REQUIREMENTS INFORMATION (QPRI). Essential information about operational and position requirements from which qualitative personnel requirements (QPR) can be formulated. QPR consists of the specifications for human capabilities in a system and the characteristics whereby such capabilities can be obtained by means of position structure, selection, training, training devices, operating procedures, handbooks of instructions and other printed material.

QUALITY ASSURANCE. With the greatly increasing proportion of inspectors in precision factories, the inspection organizations have become so large that their reporting to top management does not alone assure that a "Quality Control" group (under the same top supervision) will impartially patrol their own organization.

In some cases, management has considered the inspection as a function analogous to production, and established an organizationally separate group reporting to top (corporate) management, known as Quality Assurance, for the purpose of impartially "auditing" the quality function: e.g., the A.E.C. has contracted to a Sandia "Quality Assurance Department" the responsibility to police all inspection practices in their area; even Sandia's own inspection department.

The area generating the Quality Assurance action will vary with the organizational breakdown concerned, but the basic distinction is that it refers to an organizational concept of quality enforcement; not to any specific improved inspection technique. From the con-

tractor's point of view, the Air Force inspectors are a Quality Assurance group.

QUALITY CONTROL (U.S. GOVERNMENT USAGE). That function which enforces compliance with engineering instructions, whether given by drawing, specification or other expression. This includes responsibility for the proper execution of the following functions, with line authority varying according to company setup:

- (a) Receiving inspection—technical or functional
- (b) In-process inspection
- (c) Process control—Worker qualification
- (d) Final inspection—non-functional
- (e) Functional inspection
- (f) Material review: salvage or scrap

Quality Control is the agency to implement the requirements of the Engineering Department and management on quality by establishing sample sizes, inspection intervals, detail acceptable limits, etc., from engineering's more general specifications.

QUANTUM. An observable quantity is said to be "quantized" when its magnitude is, in some or all of its range, restricted to a discrete set of values. If the magnitude of the quantity is always a multiple of a definite unit, then that unit is called the "quantum" (of the quantity). For example, the quantum or unit of orbital angular momentum is \hbar , and the quantum of energy of electromagnetic radiation of frequency ν is $h\nu$. In field theories, a field (or the field equations) is quantized by application of a proper quantum-mechanical procedure and this results in the existence of a fundamental field particle, which may be called the field quantum. Thus the **photon** is a quantum of the electromagnetic field and in nuclear field theories, the **meson** is considered to be the quantum of the nuclear field. (The symbol h is **Planck's Constant**.)

QUANTUM THEORY OF RADIATION. The energy of radiation emitted or absorbed is concentrated in quanta or photons each with an energy in ergs of 6.624×10^{-27} times the frequency of the radiation in cycles per second.

QUARTER CHORD POINT. The **airfoil** reference point, chosen by convention, about which moments are calculated.

QUARTZ CRYSTALS. A natural mineral composed of silicon dioxide, which crystallizes in hexagonal, positive, uniaxial crystals. Two sorts are found, one rotating the plane of polarization clockwise, the other counter-clockwise. Since completely clear crystals of quartz are moderately common, and it is relatively hard (7 on the Moh scale of **hardness**) and easy to polish, quartz finds many uses in optical instruments, particularly those which use polarized light. Crystal quartz is transparent to shorter ultraviolet radiation, and to longer infrared radiation than is ordinary glass. It also has a broad band of fair transmission for infrared, starting at about 50 microns and extending far into the still-longer, infrared region. Quartz crystals are also useful as **piezoelectric** crystals.

QUENCH CIRCUIT. Super-regenerative receiver.

QUICK LOOK DATA. Those data provided at the end of a test on an expedited basis to permit rapid review of the test results. Such data, in the form of approximately calibrated oscillograph or telemetering records, direct writing recorders and films, are usually made available soon after the test.

QUICK REACTION CAPABILITY (QRC). Ability to develop a rapid counterattack.

QUIESCENT. This adjective is used in connection with vacuum tubes and other **amplifiers** to indicate the condition in which no **signal** (1) is applied to the input. The quiescent potentials of the various electrodes are therefore the *steady* undisturbed potentials of these electrodes, and the electrode currents are similarly defined.

QRC. Quick reaction capability.

R. (1) Gas constant (R), specific gas constant (r). (2) Degree Reamur ($^{\circ}R$). (3) Degree Rankine ($^{\circ}R$). (4) Radius (r), radius of nucleus (r_I), hydraulic radius (r_H). (5) Radius vector (r). (6) Radioactive range (R). (7) Roentgen (r). (8) Reluctance (\mathcal{R}). (9) Electric resistance (r or R). (10) Acoustic resistance (r). (11) Specific acoustic resistance (r). (12) Radiation resistance (R). (13) Thermal resistance (R). (14) Plate resistance (r_p). (15) Rydberg constant (R), Rydberg constant for infinite mass (R_{∞}). (16) Position vector (r). (17) Radiance or

radiant flux density (\mathcal{R}). (18) Angle of reflection (r). (19) Relative humidity (r). (20) Angular yaw (r). (21) Fuel mixture ratio (r). (22) Rate of burning (linear) of solid propellants (r). (23) Reynolds number (R or R_e). (24) Distance of body from center of earth (R).

R & D. Research and Development.

Ra. Radium.

RACE. Rapid Automatic Checkout Equipment.

RACK PANEL. A standard metal or non-metal panel upon which is mounted electronic equipment. It fits into relay or rack cabinets. (Standard width is 19 in.; available in various heights which are always multiples of $1\frac{3}{4}$ in. Mounting notches are standard, to fit multiple-drilled racks and cabinets.)

RACON. The **radar** beacon, a device that has been used for some time for the purpose of identifying ships and planes picked up on radar view scopes during military and naval operations. It is a standard aid for both air and sea navigation that may be used by all navigators supplied with radar.

RADAR. (1) Any of certain methods or systems of using beamed and reflected radio-frequency energy (radio waves) for detecting and locating objects, for measuring distance or altitude, or for certain other purposes, such as navigating, homing, or bombing. (2) The electronic equipment, sets, or devices used in any such system. (See **radio detection and ranging**; **radio direction-finding**; **reflection direction-finding** or **radar range**.)

RADAR, ACQUISITION. A radar used for early warning of an impending attack. It acquires targets and in turn passes information to fire control radar(s) or to missile guidance radar(s).

RADAR, AIR INTERCEPT (AI). An interceptor-borne radar which normally permits search for, acquisition and tracking of a target and control of an air-to-air guided missile.

RADAR ALTIMETER. An absolute **altimeter** that establishes distance from the surface of the earth by measuring the time lapse between transmission and return of a pulse of

electromagnetic waves in the communication (radio or radar) frequencies, reflected from the surface of the earth.

RADAR ASTRONOMY. The article in this book on **radio astronomy** outlines some of the great advances in knowledge of the cosmos made by investigation of extra-terrestrial radio waves. Since the development of transmitting and receiving devices for short-wave radio, discussed under **radar**, it is now possible to send radar signals from the earth to such nearby astronomical bodies as the moon, and to meteor trails, and to gain information from the radar echoes. On their journey to the moon and back, the radar waves must pass through the earth's atmosphere twice, and thus undergo other changes than those caused by lunar reflection alone. This complicates the use of the method, so that even "surveying" the moon's terrain presents difficulties. However, in overcoming them information has been obtained about the earth's **atmosphere**, particularly about the higher parts of the ionosphere, where other methods are difficult to apply. The increasing use of **pulse** techniques promises considerable extension of radar astronomy, although far more powerful transmitters would be necessary to extend its range even to Mars or Venus.

On the other hand, radar techniques have proved useful in tracking meteors. Fortunately the radar wave need not strike the meteor itself; the column of ionization produced by combustion of the meteor in the earth's atmosphere also reflects radar waves. With three or more radar stations, the direction of the meteor can be determined and its orbit calculated. As a result of this radar study of meteor orbits, it has been established that meteors are members of the **solar system**, and it is thought that they may be produced by disintegration of **comets**.

RADAR, BEACON. Beacon, radar.

RADAR BEAM. The space in front of a radar in which a target can effectively be detected and/or tracked. Its boundary is defined by custom as the loci of points, measured radially from the beam center, at which the power has decreased to one-half.

RADAR CLUTTER. Clutter, Radar.

RADAR, CONTINUOUS WAVE (C-W). A radar system in which a transmitter sends

out a continuous flow of radio energy to the target which re-radiates (scatters) the energy intercepted and returns a small fraction to a receiving antenna. Since both the transmitter and receiver are operating simultaneously and continuously, it is sometimes impractical to employ a common antenna; usually two similar antennas are employed side-by-side, so oriented that only a small fraction of the transmitted power leaks directly into the receiver. The reflected wave is distinguished from the transmitted signal by the Doppler shift in radio frequency. The C-W method has two important properties: (a) Its ability to distinguish moving targets against a stationary reflecting background. (b) A narrow bandwidth as compared to pulse radar.

RADAR CONTROL AREA. The area or airspace in which **radar control** is exercised.

RADAR, C-W DOPPLER. C-W Doppler radar.

RADAR DISH. The reflector of the radar antenna; a shaped device usually placed behind the dipole for the purpose of shaping and directing the **radar beam**.

RADAR, DOPPLER. Doppler radar.

RADAR ECHO. The radar pulse reflected back to the transmitter from a reflecting object.

RADAR EQUATION. For a radar system using the same antenna for transmission and reception, the maximum range at which an object can be detected is proportional to the fourth root of the **transmitted power**, the square root of the **antenna area**, and the square root of the frequency.

RADAR FIX. A fix obtained by means of range and bearing, on a radar target or targets.

RADAR HOMING. A method of missile guidance wherein a missile-borne radar provides the required intelligence. (See **guidance, homing; guidance, homing active; guidance, homing passive; guidance, semi-active**.)

RADAR HORIZON. The lowest elevation angle at which a radar can operate effectively owing to its **line-of-sight** propagation and the earth's curvature.

RADAR ILLUMINATION (SEMIACTIVE HOMING). A method of missile guidance wherein a radar, external to the missile but aimed at the target, causes the target to emit echoes suitable for homing.

RADAR INDICATORS. Radar scan.

RADAR, LOCKON (AUTOTRACK). That condition of radar operation where it becomes possible to track a target by automatic rather than manual means.

RADAR, MONOPULSE. A radar in which directivity is achieved by an antenna having several precisely spaced apertures—rather than by scanning. Phase comparison of the several signals yield direction.

RADAR MOVING-TARGET INDICATOR. Moving target indicator.

RADAR NAUTICAL MILE. The time interval, approximately 12.367 microseconds, required for radio-frequency energy used in radar to travel one nautical mile and return.

RADAR NAVIGATION. Air navigation by means of radar equipment and radar aids.

RADAR, PULSE. A radar which employs a transmitter that emits pulses of energy of very short duration. By measuring the time interval between transmission of a pulse and the reception of an echo pulse, the range can be determined. Pulse radars can measure distances and survey several targets simultaneously.

RADAR PULSE REPETITION FREQUENCIES (PRF). The pulse repetition rates which occur in radars. They vary from approximately 200 to 2,000 per second. The ratio

$$\frac{\text{pulse duration}}{\text{total period from start of one pulse to the next}}$$

is called the duty cycle and in most installations lies between approximately 0.0005 and 0.002.

RADAR RANGE. (1) The maximum distance at which a radar set is ordinarily effective in detecting objects. (2) The distance at which a radar set can detect a specified object at least fifty percent of the time. The theoretical maximum free-space range, R , of a radar using an isotropic common receiving

and transmitting antenna, lossless transmission line, and a perfect receiver, is given by the following equation (which assumes that the receiver adds no noise, and that the signal is visible on the indicator when signal and noise energies are equal) (See figure on Page 489):

$$R = \left[\frac{P_t A_e \lambda^2}{(4\pi)^3 (KT)} \right]^{1/4} = \left[\frac{P_t K A_t A_r A_e}{P_m (4\pi)^2 \lambda^2} \right]^{1/4} \\ = \left[\frac{P_t G A_r A_e}{P_m (4\pi)^2} \right]^{1/4}$$

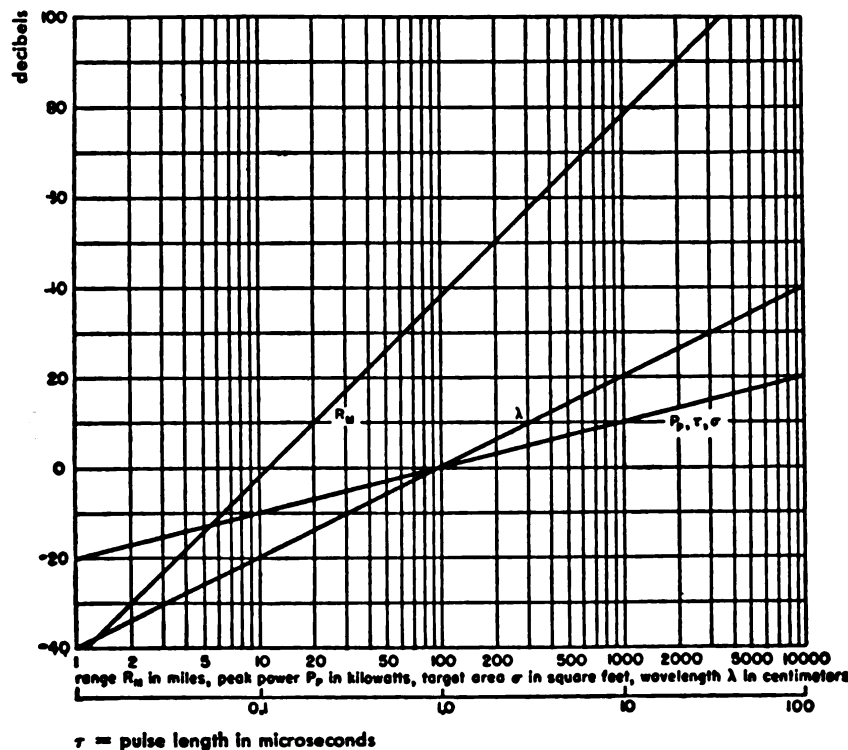
where λ is the wavelength, A_t is the effective area of transmitting aerial, A_r is the effective area of receiving aerial, A_e is the effective radar or echoing area of the target, G is the power gain of transmitting aerial, $k = G\lambda^2/A_t$ is the constant for the particular type of transmitter aerial, P_t is the peak transmitted power, P_m is the minimum power required for detection, transmitted pulse energy is $P_t X \tau$, energy incident on target is $P_t \tau / A \pi R^2$ per unit area, energy returned to antenna is $P_t \tau A_e / (4\pi R^2)^2$ per unit area, energy at receiver input is $P_t \tau A_e \lambda^2 / (4\pi)^3 R^4$ and receiver input-noise energy is $KT = 4.11 \times 10^{21}$ joules.

From the above relationship it is apparent (1) that the range is proportionate to the fourth root of transmitter power; (2) that doubling P_t only increases range by about 20 per cent; (3) that to double the range, P_t must be increased 16 times; (4) that range is increased by decreasing the wavelength. This is because the beam becomes narrower, and G is consequently increased.

RADAR RANGE MEASUREMENT. In conventional pulse-type radar sets the basis of range determination is measurement of the elapsed time from transmission of a pulse until it has been reflected by the target and returned to the radar receiver. This time is a period twice as long as would be required for the one-way travel of an electromagnetic wave over the distance in question. The rate of travel of all electromagnetic waves is the same (186,000 miles per second or 2.998×10^{10} centimeters per second, or 299.8 meters per microsecond). Return times (i.e., time out and back) for radar pulses to travel various ranges are:

1 microsecond = 149.85 meters or 163.88 yards or 491.8 feet

6.673 microseconds = 1 kilometer



The radar range equation.

10.739 microseconds = 1 statute mile
12.366 microseconds = 1 nautical mile

The maximum range of any radar set yet constructed is the distance to the moon (239,000 miles). The rest time between pulses from this set was approximately two seconds.

Doppler radars are often used for range measurement, as shown in the figure at the top of Page 490.

RADAR, REFLECTION INTERVAL. The length of time required for a radar pulse to travel from the source to the target and return to the source, taking the velocity of radio propagation to be equal to the velocity of light, 2.998×10^8 m/sec, or 299.8 m/micro-sec. Since the pulse must travel, in all, twice the distance to the target (out and back), the apparent velocities obtained are only one-half of the true velocity of the pulse. Likewise, the reflection intervals are exactly twice as great when target ranges are considered.

RADAR REPEAT-BACK GUIDANCE. A guidance system for guided missiles using a search radar in the missile which transmits information to the point of control.

RADAR RESOLUTION. The ability of a radar to distinguish between a desired target and its surroundings.

RADAR, SCAN. A mode of radar operation wherein the beam direction is systematically changed in order to search for or track a target more effectively, e.g., circular, conical, spiral, helical, or rectangular. (See figures at bottom of Page 490.)

A-scan—An indicator with a horizontal or vertical sweep, giving range only. Signals appear as deflections on the time scale.

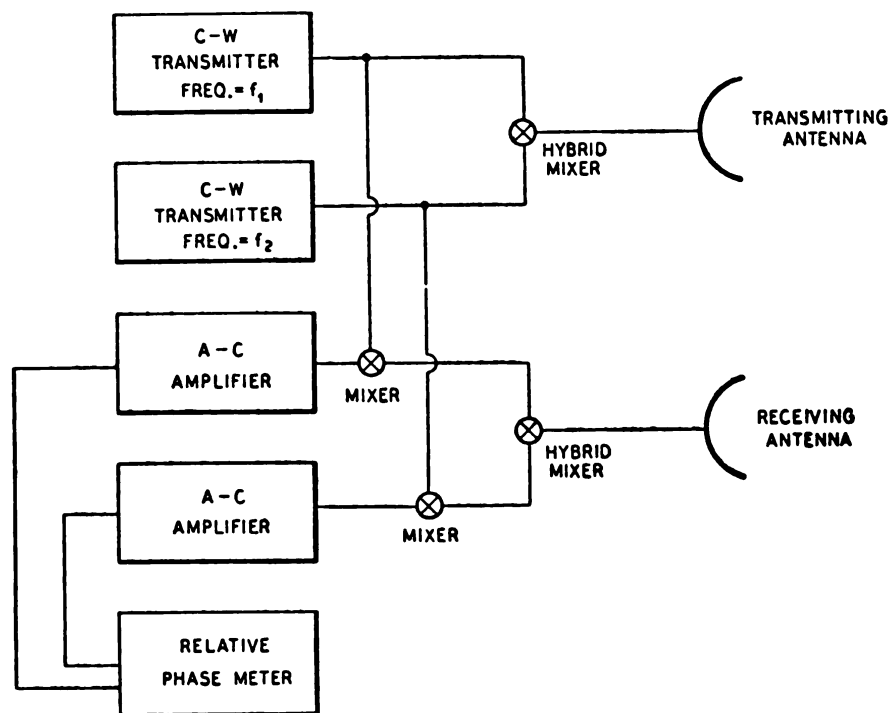
B-scan—Type of presentation in which signal appears as a bright spot with azimuth angle as the horizontal coordinate and range as the vertical coordinate.

C-scan—Type of presentation in which signal appears as a bright spot with azimuth angle as the horizontal coordinate and elevation angle as the vertical coordinate.

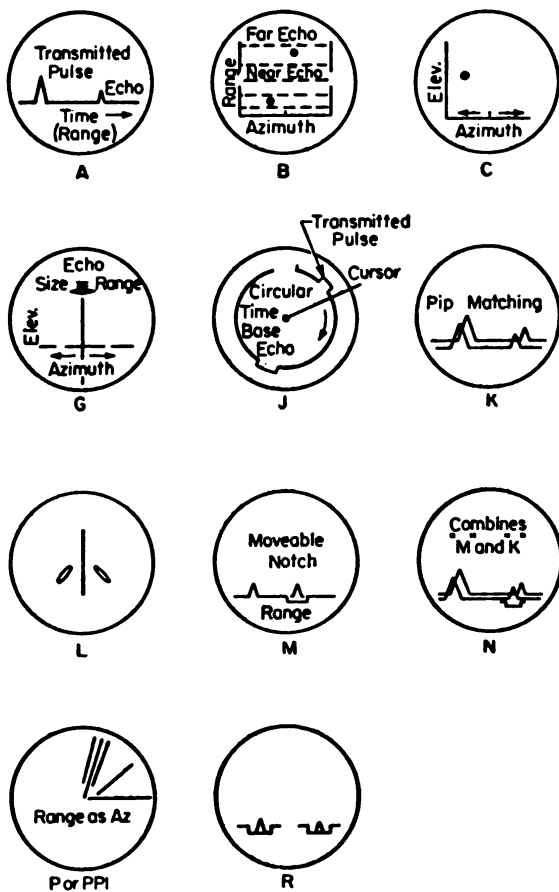
D-scan—Presentation combining B and C types. The signal appears as a bright spot with azimuth angle as the horizontal coordinate and elevation angle as the vertical coordinate. Horizontal trace is expanded vertically by a compressed time sweep to facilitate separation of signal from noise and give a rough range indication.

E-scan—A modification of B-scan. Signal appears as a bright spot with range as horizontal and elevation as vertical coordinate.

F-scan—A single signal only, appearing as a bright spot. Azimuth error angle (relative



Range-measuring Doppler radar.



Radar oscilloscope presentations by type.

bearing) appears as the horizontal coordinate, elevation angle as the vertical coordinate.

G-scan—A single signal only, appearing as a bright spot on which wings grow as the distance to the target is diminished. Azimuth angle appears as the horizontal and elevation angle as the vertical coordinate. This has been referred to as Mark VI indication.

H-scan—A modification of B-scan. Signal appears as a bright line the slope of which is proportional to the sine of the angle of elevation. Azimuth appears as the horizontal coordinate, and range as the vertical coordinate.

J-scan—A modification of type A in which the time sweep produces a circular range scale near the circumference of the CRT face. The signal appears as a radial deflection of the time trace. No bearing indication is given.

K-scan—This type uses pip height matching. When the two pips are equal in height, the nutating antenna lobes have the target bracketed.

L-scan—Azimuth is determined when deflections to left and right have equal magnitude. The antenna crossover is then pointing toward the target. Two antennas are re-

quired or a lobe switching arrangement must be provided.

M-scan—Uses a moveable notch which can be used to show range value by amount of distance the notch has moved.

N-scan—Is a combination of "M" and "K" using a range gate to indicate value. Adjustment is done by matching traces.

P-scan (or PPI)—This type gives slant range and azimuth. The PPI display has a radial time base trace starting from the center of the screen. The direction of sweep is continuously rotated in synchronism with the antenna direction. Targets are indicated by a momentary brightening on the screen. The PPI display gives a radar map of all the targets within range. Range is indicated by aid of calibration rings produced by brightening the sweep trace at intervals.

R-scan—An expanded "N" with pips and gates and with the remainder of the radar-scope blocked out.

RADAR SET. A set of electronic apparatus consisting principally of a radio transmitter, antenna, receiver, and indicator for sending out scanning beams and receiving and displaying the reflected waves (or the waves emitted by a radar beacon)—sometimes distinct from a radar beacon. (See **radar**.)

RADAR "TARGET." Any reflecting surface in the beam of the radar antenna which causes a signal to be returned to the receiver.

RADAR WAVELENGTHS. At the present time, missile tracking radars operate in the UHF band of frequencies or higher (shorter wavelengths). For search radars where sensitivity at long range is more important than accurate location, wavelengths of the order of 10-15 centimeters (L-band, up to 3000 mc/s) are used. For accurate work at shorter ranges, a narrower beam is desired and wavelengths of 3-10 centimeters (X-band and K-band, up to approximately 20,000 mc/s) are used.

RADARSCOPE. The cathode-ray oscilloscope or screen in a radar set. (See **radar**, **Scan**.)

RADC. Rome Air Development Center; Griffis Air Force Base; Rome, New York.

RADIAC. The act or process of detecting, identifying, and measuring the intensity of nuclear radiation in an area.

RADIAC INSTRUMENT. An instrument, such as a dosimeter or Geiger-Mueller counter, used in **radiac**.

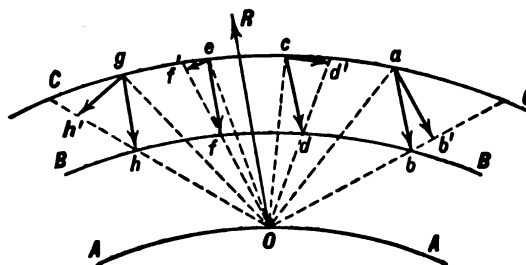
RADIAL VELOCITY. Relative velocity between two bodies measured along a line between their centers. If they are approaching, the radial velocity is positive.

RADIANT ENERGY. Energy transmitted as electromagnetic **radiation**.

RADIANT FLUX. The time rate of flow of radiant energy.

RADIANT POINT. If the paths of all of the meteors observed from a single station on a given night are plotted on a chart of the sky, it will usually be found that a number of them seem to be coming from a certain particular point in the sky. Such a point is known as a meteor radiant point, and the group of meteors associated with the radiant point is known as a **meteor shower**. It will further be noticed that, among the meteors belonging to the shower, those at the greater distance from the radiant point will have the longer trails.

This observed effect is merely due to the perspective view of a number of meteors actually entering the atmosphere of the earth in parallel paths. The accompanying figure



Explanation of radiant point.

represents the cause of the radiant point. The circular segment AA represents the surface of the earth with the observer at O. CC represents the upper part of the atmosphere of the earth where the meteors first become visible, and BB the lower atmosphere where the meteors burn out and disappear. *ab*, *cd*, *ef*, and *gh* represent the actual parallel paths of four

meteors through this layer of atmosphere, and ab' , cd' , ef' , and gh' represent the paths as observed from O . Examination of the figure will show that the apparent paths all radiate from a point in the direction R , the radiant point, which is a direction parallel to that in which the meteors are actually entering and traveling through the atmosphere. It will further be noted that the meteors more distant from the radiant point, e.g., ab' and gh' , have apparently longer trails than the nearer ones, cd' and ef' .

RADIATION. (1) The emission and propagation of energy through space or through a material medium in the form of waves; for instance, the emission and propagation of electromagnetic waves, or of sound and elastic waves. (2) The energy propagated through space or through a material medium as waves; for example, energy in the form of electromagnetic waves or of elastic waves. The term radiation, or radiant energy, when unqualified, usually refers to electromagnetic radiation; such radiation commonly is classified, according to frequency, as Hertzian, infra-red, visible (light), ultraviolet, x-rays, and γ -rays. (3) Corpuscular emissions, such as α - and β -radiation, or rays of mixed or unknown type, as cosmic radiation.

RADIATION, COSMIC. Cosmic rays.

RADIATION DOSAGE. The measurement and control of the radiation absorbed by man, in the many activities using radioactive materials and radiations, is complicated by certain factors. The most important of these is the necessity for distinguishing between the physical measurements and the biological absorption, and even in the case of the latter, the portion of the body by which it is absorbed. Thus the *dose* of radiation may be the radiation delivered to a specified area or volume or to the whole body. Units for dose specification are the roentgen for x-rays and gamma rays, reps or rems (equivalent roentgens) for β -rays. The subject of dose units for particulate radiation and for very high energy x-rays has not been settled. In radiology the dose may be specified in air, on the skin, or at some depth beneath the surface; no statement of dose is complete without specification of location. The International Commission on Radiological Units (July, 1953) in its revised recommendations, estab-

lished the "*absorbed dose* of any ionizing radiation as the amount of energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. It is expressed in rads."

The Commission discussed the measurement of absorbed dose as follows: "Since the calorimetric methods of determining absorbed doses are not usually practicable, ionization methods are generally employed. The quantity which must be measured is the ionization produced in a gas by the same flow of corpuscular radiation as exists in the material under consideration. The energy, E_m , imparted to unit mass of the material is then essentially related to the ionization per unit mass of gas, J_m , by the equation

$$E_m = WsJ_m$$

where W is the average energy expended by the ionizing particles per ion-pair formed in the gas, and s is the ratio of the mass stopping power of the material to that of the gas. Since the calculation of the absorbed dose from measurements of ionization requires a knowledge of the parameters W and s as well as variables characterizing the radiation and the irradiated material, it is recommended that tables of the best available data be prepared and held under continual review."

The permissible dose is the amount of radiation which may be received by an individual within a specified period with expectation of no harmful result to himself. For long-continued x- or γ -ray exposure of the whole body it is 0.3 roentgen per week measured in air in American practice, although lower limits are in force in some places. Needless to say, these limitations do not apply to the therapeutic or diagnostic uses of radiation.

RADIATION, ELECTROMAGNETIC. Electromagnetic radiation.

RADIATION EFFICIENCY. The ratio of the power radiated to the total power supplied to an antenna at a given frequency.

RADIATION FIELD. When a conductor carries a-c there are two types of fields set up in the surrounding space. One of these, the induction field, is predominant at low frequencies such as used in power circuits, while the other, called the radiation field, predominates at very high frequencies such as used for radio communication. The induction field

is responsible for the familiar magnetic effects of **coils** and the interference between circuits which are coupled inductively, i.e., the induction field of one links the other. For radio communication over long distances the radiation field is important since it represents the energy which is radiated outward from the **antenna** system and which does not return to the system but spreads out in space. Close to the transmitting station both types of field may be utilized; in fact, certain wireless record players use the induction field, but at appreciable distances (a few wavelengths) the induction field is negligible. The radiation field consists of an electromagnetic wave traveling at the velocity of light (3×10^{10} cm/sec). It is this wave which cuts across the receiving antenna and induces the signal which is amplified and demodulated in the **receiver**. This radiation goes out from the antenna in various directions, the exact directions and strengths being dependent upon the antenna characteristics. Thus some of the energy may travel along the earth's surface to the receiver, some may go upward to the **ionosphere** and be refracted so it is returned to the earth giving long-distance communication. This radiation field is composed of an electric and a magnetic component, mutually perpendicular and perpendicular to the direction of propagation. Upon leaving the antenna the electric field is parallel to the antenna and the magnetic perpendicular to it. Either or both may contribute to the signal induced in the receiving antenna. At extremely high frequencies the polarization or direction of the electric field or vector has an effect on the character of the received signal.

RADIATION, INFRARED. Infrared radiation.

RADIATION INTENSITY. In a given direction, the power radiated from an **antenna** per unit solid angle in that direction.

RADIATION LOBE. A portion of the **radiation pattern** bounded by one or two cones of **nulls**.

RADIATION LOSS. That part of the **transmission loss** due to radiation of radio frequency power from a transmission system.

RADIATION PATTERN. A graphical representation of the radiation area covered by

an antenna as a function of direction versus strength. Cross-sections in which radiation patterns are frequently shown are the vertical plane, the horizontal plane, or the principal electric and magnetic polarization planes. In order to show the relative amount of radiation in each direction, the pattern of an isotropic radiator is usually included in drawings of radiation patterns. An isotropic radiator is one that radiates equally in all directions in the plane under consideration.

RADIATION SHIELD. A shield or wall of some material, as lead, for blocking **nuclear radiation**.

RADIATION SICKNESS. Sickness caused by overexposure to ionizing radiation, especially by overexposure to **nuclear radiation**. The chief cause of radiation sickness is the loss of white blood cells in the lymphatic tissues of the body, resulting in increased susceptibility to bacterial infections.

RADIATOR. (1) A body which emits energy quanta or certain material particles; more commonly a body which emits **electromagnetic radiation**. (2) A substance placed in a beam of radiation, which as a result of the interaction of the beam with the substance, emits radiation of a different type. For example, a metal foil placed in a beam of γ -radiation will emit secondary electrons as a result of the **photoelectric** and **pair production** processes. (3) A radiating element, which may be (a) a vibrating element in a **transducer** which can cause, or be actuated by sound waves, or (b) a basic subdivision of an **antenna**, which in itself is capable of radiating or receiving radio-frequency energy.

RADIO. (1) Electromagnetic waves used to transmit or receive electric impulses or signals without a connecting wire; the transmission or reception of such impulses or signals. (2) The use of these waves to transmit electric impulses excited by the voice or other sounds, or by nonauditory instruments at frequencies below those normally used in **radar** or television. (3) Any aggregate of electric and electronic equipment used for the wireless transmission or reception of electromagnetic waves, or both, especially for transmitting and receiving sound activating remote-control mechanisms, etc.; a radio set.

RADIO ASTRONOMY. The basis of radio astronomy is the fact that various **stars, planets, nebulae** and other bodies and regions of the universe are the source of radio waves. Data on these radio waves can be interpreted to disclose information of astronomical importance, just as data on visible light, and other extraterrestrial electromagnetic radiations, has long been interpreted to reveal so much of the known facts of astronomy.

Radio astronomy may be dated from the work of Dr. Karl J. Jansky in the years 1928-1932. He was engaged in studying certain factors, primarily the static and interference noises, affecting the operation of the Bell System transoceanic radiotelephone circuits. One type of equipment that he used for this purpose consisted of a 14.6 meter (20.53) rotatable **directional antenna**. Among the types of static he found, there was one that he could not attribute to terrestrial sources (that is, to sources on the earth or in the earth's atmosphere). He concluded that this kind of static was apparently of extraterrestrial origin, and that it apparently came from a direction fixed in space, having coordinates of 18 hours **right ascension** and -10° **declination**.

This report by Dr. Jansky was the beginning of a period of intensive investigation of radio waves from all directions of the sky, and later of the use of radar techniques as an aid to astronomy. The latter are discussed in this book under **radar astronomy**. The results of the former will be covered in this article, following a brief account of their methods.

The diagram in Fig. 1 shows the four essential elements of the equipment used by radio astronomers. The radio telescope col-

lects and focuses the radio waves, just as an optical telescope does for light waves. There are various types of radio telescopes, of which the George B. Agassiz radio telescope is typical. Its paraboloidal reflector focuses the radio waves upon a small dipole antenna, whence the induced voltages send currents to the radio receiver. The latter in turn actuates a display device. The latter may be electrical (for example, a milliammeter or other current measuring device actuating a pen mounted on a moving chart); or acoustical (for example, a loudspeaker); or even optical (for example, a cathode-ray tube). The fourth, and last, element in the equipment shown in Fig. 1 is a noise calibrating device. This is necessary because the radio astronomy apparatus is so sensitive that sources of noise that are inseparable from the normal functioning of its own parts (for example, variation in temperature of the filaments of vacuum tubes in the receiver) would mask the signal from the sky. Therefore, the noise calibration unit is used to calibrate the receiver, and a switch or switching mechanism is provided so that the calibration can be carried out manually or automatically.

The description just given covers the fundamental equipment of radio astronomy. For many, if not most, actual measurements, additional equipment is necessary, although much of it is essentially a multiplication of elements already described. For example, a dipole may have several focusing rods put ahead of it to improve the aperture. Again, by use of two separate antennas a system may be designed to function as an optical **interferometer** does. This system is useful in determining not only the direction, but even the position and angular diameter of the objects

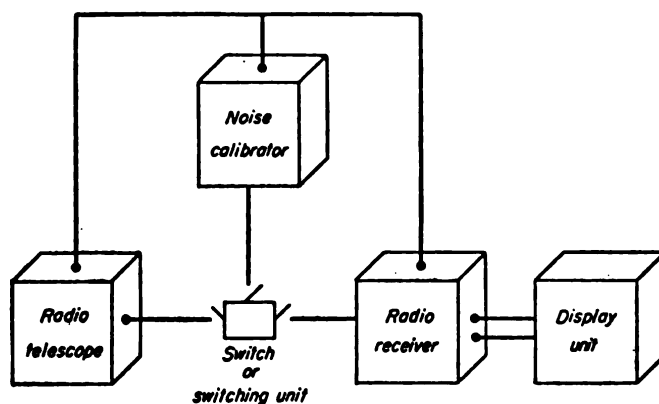


Fig. 1. Block diagram of major units in a unit used in radio astronomy.

or regions of the sky emitting radio waves.

Various classes of such objects and areas have been found. One class for which the discoveries have been most numerous are the so-called "radio stars." The use of radio telescopes has pointed out numerous "radio stars," some of which are invisible optically, and cannot be said to be necessarily identical with the stars seen in optical telescopes. The brightest "radio star" was found in the constellation Cassiopeia, in a position where no object had been discovered previously. Following the radio discovery, careful search of the area by the 200-inch Mount Palomar telescope detected a very faint nebula, which is presumably undergoing some unusual process, to account for its high radio-wave activity. The second brightest "radio star" was photographed by the Schmidt telescope at Mount Palomar as a result of the radio discovery.

The discoveries of radio astronomy are by no means limited to far distant parts of the cosmos; some of the most interesting have been made about our own sun. Radio study of sunspots has been particularly fruitful. This is evident from Fig. 2, which shows the time-relationship of radio signals at three frequencies obtained from one of the bright flares of light that is often found near a sunspot. Such flares are found to be sources of

intense radio-wave radiation, and Fig. 2 shows that this radiation is received on earth first in the 200-megacycle frequency, then in the 100-megacycle frequency, and still later in the 50-megacycle frequency. The conclusion drawn from these observations is that the intense radio source is moving out from the sun, and as it passes through the ionized layers in the sun's corona, it can emit radiation of lower frequency (lower energy) or that this less energetic radiation can get through. This leads to the further conclusion that a stream of corpuscles from the sun are actually traveling toward the earth. This is confirmed by the enhancement of upper atmosphere activity (intensified aurora and increased static) about 24 hours later.

There are other sources of radio-waves within our Solar System. In fact, the planet **Jupiter** is the most intense of all the extra-terrestrial sources. Since the temperature of the clouds on this planet is believed to be about $-140^{\circ}\text{C}.$, it is more difficult to explain the source of radiation. (The liquid drops in these clouds are believed to be largely ammonia and methane.) Of course, much of it may be attributed to a cause familiar on earth, namely to **lightning**. Careful observations have shown that the high point of origin of the noise is close to the most conspicuous "landmark" on the surface of the planet, the

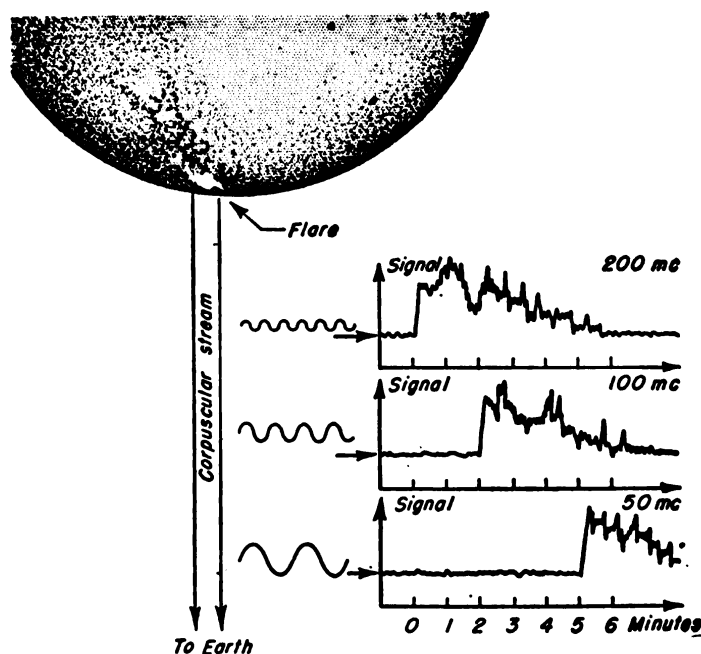


Fig. 2. Radio signals produced by corpuscular stream as it travels through the atmosphere of the sun. (Photograph taken at the Astrophysical Observatory, Kodaikanal, India.)

famous red spot. However, there are fluctuations in this radiation with changing positions of the red spot; and clarification of the subject awaits further observations and analysis.

Still another source of radio-waves is our galaxy, the **Milky Way**. In fact, the pioneer discovery of Jansky cited at the beginning of this article, placed the direction of his observed extra-terrestrial static at right ascension 18 hours, declination -10° . This is thus close to the center of the galaxy, a region that is largely screened from *optical* observation by dust clouds. Therefore, the nature of the source of the radio-waves has not been observed. Analysis of the radio-wave spectrum discloses one component at a wavelength of 21 centimeters, which is of interest because it is known to be produced by the normal hydrogen atom by a very infrequent transition, of low energy. From these known characteristics of the radiation, and the observed intensity of the radio-wave of this length, the temperature and density of the hydrogen emitting the signal can be calculated. Moreover, by a **Doppler effect**, its velocity may also be calculated. As a result, it has been found that neutral hydrogen is most prevalent in the spiral arms of our galaxy, and that these arms probably extend far beyond the positions observable with optical telescopes, because of the obscuring effect of the intragalactic dust clouds. (See also **radar astronomy**.)

RADIO BEACON. (1) Any radio transmitter, including its antenna and other associated equipment, that provides navigational aid to air vehicles. (2) A **homing** beacon.

RADIO BEAM. (1) A stream of radio-frequency energy. (2) A **radio-range** beam.

RADIO BEARING. A bearing taken by an air or surface vehicle in relation to a radio-transmitting station by means of a **radio compass** or otherwise.

RADIO CHANNEL. A band of frequencies of a width sufficient to permit its use for radio communication. The width of a channel depends upon the type of transmission, and the tolerance for the frequency of emission.

RADIO COMMAND. A radio signal to which a guided missile responds.

RADIO COMPASS. This is probably the most loosely used term in all navigation.

When the loop antenna was first applied to the determination of **radio bearings**, the term radio-compass station was applied to shore installations that would forward, on request, the bearing of a ship from the station. Next the term was applied to a group of shore installations, each equipped with a loop antenna, from which the navigating officer of a ship within range could obtain the **latitude** and **longitude** of his ship. After the loop antenna and receiving sets had been developed to a state where they could be carried by the ships themselves, the term radio compass was applied to the loop. As new and improved radio equipment became available, the term radio compass was successively applied to any radio device that could be used to determine bearing. A glance through any textbook on navigation, particularly those dealing with air navigation, will yield at least two, and sometimes as many as five, different instruments for the name radio compass.

RADIO CONTROL. (1) The **guidance** and direction exercised over a pilotless aircraft or guided missile, by means of radio-frequency energy activating certain mechanisms or apparatuses within the aircraft, missile, etc. (2) Any aggregation of radio equipment and other equipment or devices for exercising this control.

RADIO DECEPTION. Deception, radio.

RADIO DETECTION AND RANGING. Unabbreviated form of **radar**.

RADIO DIRECTION-FINDER. A radio-receiving set, together with a directional antenna and any other associated equipment, for determining the direction from which a transmitted signal originates.

RADIO DIRECTION-FINDING. The act or process of determining the direction from which a transmitted signal originates. Hence, a method for establishing the bearing or position of a missile, or air or space vehicle.

RADIO FADEOUT. Fading.

RADIO FIELD STRENGTH. The **electric** or **magnetic field strength** at a given location resulting from the passage of radio waves. In the case of a sinusoidal wave, the root-mean-square value is commonly used. Un-

less otherwise stated, it is taken in the direction of maximum.

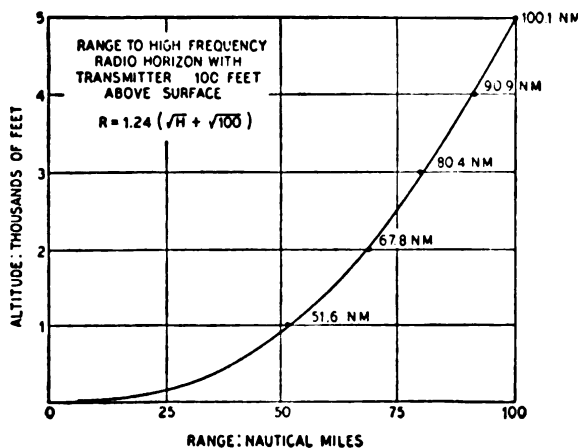
RADIO FIELD-TO-NOISE RATIO. The ratio of the **field strength** of the desired wave to the field strength of the noise, measured at a given location.

RADIO FIX. A radio bearing or bearings to determine geographical position.

RADIO FREQUENCY. (1) A frequency at which coherent electromagnetic radiation of energy is useful for communication purposes. Radio frequencies are designated by the U.S. Federal Communication Commission as follows: very low frequency, 10-30 kilocycles; low frequency, 30-300 kilocycles; medium frequency, 300-3,000 kilocycles; high frequency, 3,000-30,000 kilocycles; very high frequency, 30-300 megacycles; ultrahigh frequency, 300-3,000 megacycles; superhigh frequency, 3,000-30,000 megacycles. (See also **extremely high frequency**.)

RADIO GUIDANCE. A form of **guidance** in which commands are transmitted to a missile from a remote location by means of systematic modulation of radio-frequency signals.

RADIO HORIZON. The distance to the radio horizon for a given antenna height. (See figure.) The effect of the earth's curva-



Range to radio horizon as function of VHF-UHF receiver altitude.

ture can be taken into account, approximately, by assuming the radius of the earth to be $\frac{4}{3}$ its actual value. For radio horizons over water, the earth's radius should be doubled.

RADIO-INERTIAL GUIDANCE. **Guidance, radio-inertial.**

RADIO INTERFERENCE. Any noise which interferes with the reception of a desired signal.

RADIO MAGNETIC INDICATOR. A navigational instrument coupled with a gyro **flux-gate compass** or similar compass that indicates the direction of an **omnirange station** and its bearing with respect to the observer.

RADIO NAVIGATION. The use of radio aids to check the dead-reckoning position of a vehicle. **Lines of position** from known points having radio beacons are plotted to give intersection fixes. The three common types of radio navigation are: *radial*, *circular* and *hyperbolic*. Each of these makes use of the direction and time of transmission of signals from stations of known position to the observer's vehicle whose position is unknown.

RADIO NAVIGATIONAL AID. Any radio device, as a **radio range**, radio marker beacon, or other radio apparatus, device, or system designed as an air-navigation aid. Distinguished from a **radar navigation aid**.

RADIO NAVIGATION GUIDANCE. The guidance or control of a guided missile in which the missile flies along a course established by external radio transmitters. (See **hyperbolic guidance**.)

RADIO RANGE. (1) The reach of a radio beam or the reach and scope of radio beams emitted by a given station for use as directional signals for airborne vehicles, the flight-path course directions, and position signals provided by these beams. (2) The station or installation that sends out such directional beams.

RADIO-RANGE BEACON. Any **radio beacon** or radio marker beacon in a **radio range**, especially the central or main radio transmitter, together with its associated equipment, that sends out directional signals.

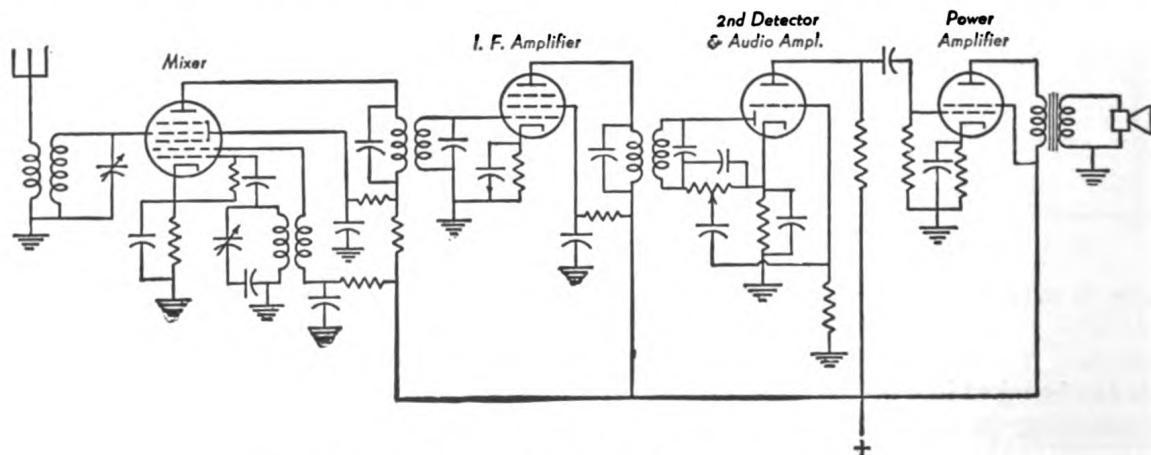
RADIO SPECTRUM. **Spectrum.**

RADIO RECEIVER. The radio receiver is the device which picks up the wave from the transmitter and converts it to sound. The simplest form of practical receiver is the

crystal set which was once used extensively, then with the advent of satisfactory and cheap vacuum-tube circuits was largely discarded, and which is now coming back as a receiver for ultrahigh and superhigh frequencies. Such a set consists of some means of selecting or tuning the desired signal, a rectifying type crystal (galena, silicon, etc.) as a **detector** and a head-set. In its present application for the extremely high frequencies the tuning elements are lines and **wave guides**. In the early days of broadcasting the regenerative receiver was almost universally used. However, it has serious limitations, chief among them being its poor audio quality and its radiating ability. As a consequence it is no longer used for regular broadcast reception and its present use is confined to the reception of continuous wave signals, as in radio telegraphy. Tuned radio-frequency receivers were also widely used at one time but are not used much except in the cheaper broadcast receivers and in some long wave commercial stations. This receiver has an antenna-coupling circuit for tuning and coupling the **antenna** to the **grid** of the first amplifier **tube**. This tube may be coupled by a second tuned circuit to another **amplifier** or in smaller sets it may be coupled to the **detector**. Each coupling circuit up to the grid of the detector is tuned and for home receivers the present-day sets have all tuning elements controlled by a single dial. Early sets had each element controlled by a separate dial. While the detector may be any of the conventional types it is usually a triode biased almost to cut-off. This produces rectification and hence demodulation of the radio signal. The audio output of the detector is then am-

plified by one or more audio-amplifier stages and fed to the speaker where it is converted to sound.

The superheterodyne receiving circuit differs from others in that it converts all incoming radio-frequency signals to a common carrier frequency. This is accomplished in the first detector, mixer or converter as it is variously called. The signal from the antenna is fed by a tuned coupled circuit to the mixer tube (or in more elaborate sets a tuned radio-frequency stage may be inserted between the antenna and the mixer). In the mixer stage the incoming signal is heterodyned with a locally generated signal so a beat frequency signal, called the intermediate frequency, is produced. This new frequency signal is radio frequency, ranging from around 450 kc to several megacycles depending upon the purpose for which the receiver is designed. The intermediate frequency has exactly the same modulation as the original signal. In many broadcast receivers the mixer tube combines the functions of mixer and oscillator by using a multiplicity of grids (the **pentagrid converter** is an example of such a tube). However, at higher frequencies it is desirable or even necessary to use a separate tube for **oscillator** and feed its output into the mixer. Regardless of how the oscillator operates, its frequency is always adjusted by the main tuning control of the receiver so the beat frequency output of the mixer is a fixed value. This intermediate frequency signal is then amplified by fixed-tuned radio-frequency amplifiers and then fed to the detector (commonly called the second detector) where it is demodulated. The audio is then further am-



Simplified circuit diagram of superheterodyne receiver.

plified and coupled to the speaker. The simplified-circuit diagram will serve to indicate the various circuits and their relative positions. In some of the cheaper superheterodynes the antenna signal is coupled to the pentagrid first detector, then the intermediate frequency output of this coupled without further amplification to a grid bias or regenerative detector and hence to the final power tube.

RADIO TRANSMITTER. Transmitter.

RADIO WAVE—PLANE OF POLARIZATION. In a propagated electromagnetic wave, the direction of the electric field with respect to the earth's surface.

<i>Vertically polarized</i>	—electrical field is vertical
<i>Horizontally polarized</i>	—electrical field is horizontal
<i>Circularly polarized</i> <i>Elliptically polarized</i>	{ —electrical field is caused to rotate during propagation.

RADIO WAVE PROPAGATION. The transfer of energy by electromagnetic radiation at frequencies lower than about 3×10^{12} cycles per second.

RADIO WAVE SCATTERING. A process which occurs when a radio wave strikes a surface too rough to support specular (or mirror-like) reflection. Scattering may occur when a wave passes through a nonhomogeneous medium. Anomalies of the index of refraction of the earth's atmosphere produce some scattering. Scattering also occurs when a radio wave strikes raindrops, fog, hail or snow in the earth's atmosphere. Condensed water and other forms of precipitation are capable of both scattering the incident radiation and absorbing energy from the radio waves. The amount of energy which is lost by scattering is a function of the radio frequency and the size, shape, distribution, and index of refraction of the particles in the atmosphere.

RADIOACTIVE BATTERY. An electric power supply which connects nuclear radiation directly into useable electric energy.

RADIOACTIVE SERIES. A succession of nuclides, each of which transforms by radio-

activity into the next until a stable nuclide results. The first member is called the parent, the intermediate members are called daughters, and the final stable member is called the end product. Three such series are encountered in natural radioactivity, and many others are encountered in induced radioactivity, particularly among the heavy elements and fission products. The process of successive radioactive transformations in such a series is known as series disintegration. A series of induced radionuclides that merges into a natural series is called a collateral series to the latter.

RADIOACTIVITY. (1) Spontaneous nuclear disintegration with emission of corpuscular or electromagnetic radiations. The principal types of radioactivity are α -disintegration, β -decay (negatron emission, positron emission, and electron capture) and isomeric transition. Double β -decay is another type that has been postulated, and spontaneous fission and the spontaneous transformations of mesons are sometimes considered as types of radioactivity. To be considered as radioactive, a process must have a measurable lifetime (between $\sim 10^{-10}$ sec and $\sim 10^{17}$ yr, according to present experimental techniques). Radiations emitted within a time too short for measurement are called prompt; however, prompt radiations, including γ -rays, characteristic x-rays, conversion and Auger electrons, delayed neutrons, and annihilation radiation, are often associated with radioactive disintegrations, since their emission may follow the primary radioactive process. (2) A particular radiation component from a radioactive source, such as γ -radioactivity. (3) A radionuclide, such as a radioactivity produced in a bombardment. (4) A synonym for activity.

RADIOMETER. A device for measuring the flux density of either total radiation, or of radiation in a particular frequency band, especially infrared radiation. A radiometer usually comprises a sensitive detector, such as a thermocouple; an optical system, such as a paraboloidal mirror aluminized on its front surface, to form an image of an object or a selected area on the thermocouple; and some means of measuring the thermocouple voltage, such as a galvanometer or an ultrasensitive voltmeter.

RADIOMICROMETER. An instrument sensitive to very small quantities of radiation, which measures intensities accurately.

RADIOSONDE. An instrument which fulfills the same functions as the **aerometeorograph** but to much greater altitudes. A pilot balloon carries the instrument aloft; a parachute lowers it to earth again when the balloon bursts in the upper atmosphere. By means of a clockwork motor and very light weight radio-transmitting set, the indications of instruments sensitive to pressure, temperature and humidity are automatically transmitted at regular intervals during the flight. The signals from the radiosonde are received and recorded on a special receiver on the ground, and are then translated into readings of pressure, temperature and humidity at the various altitudes. Sometimes the instrument is tracked by radar to verify altitude.

RADIUM. Radioactive element. Symbol Ra. Atomic number 88.

RADIUS OF GYRATION. The square root of the ratio of the **moment of inertia** to the **mass**. If the mass of a body were concentrated at one point while preserving the same moment of inertia about an axis of rotation, the distance from this point to the axis of rotation would be the radius of gyration.

RADIUS VECTOR. In astronautics, the line connecting the center of a **central force field** with an **infinitesimal body** moving in it.

RADIX. The base of a number system. For example, ten is the radix of the decimal number system and two is the radix of the binary system. (See also **number**.) The *radix point* is the index which separates the digits associated with negative powers from those associated with the zero and positive powers of the base of the number system in question. The binary point and the decimal point are the most common examples.

RADOME (RADAR DOME). The housing for a radar antenna, essentially transparent to radio frequencies.

RADCM. Radar Countermeasures and Deception.

radl. Radiological.

Radlab. Berkeley Radiation Laboratory.

Radlwar. Radiological Warfare.

RAIL TYPE LAUNCHER. Launcher, Rail Type.

RAIN. Water drops in the atmosphere ranging in diameter from 0.5 mm to approximately 5.0 mm, usually falling with velocities ranging from 3 m per sec. to 8 m per sec. Rain is the most common type of precipitation.

RAKED. Having a characteristic inclined shape. Raking is applied to the tip contour of an airfoil to decrease **drag** and increase **lift** through reduction of tip vortices and other tip interferences. Raking is positive when the **trailing edge** is longer than the **leading edge**. (See also **sweepback**.)

RAM. (1) The forward motion of an air scoop or air inlet through the air. (2) A ram effect as manifested in increased pressure and higher temperature. (3) An anti-tank rocket fired from airplanes. U.S. Navy carrier-based planes used Rams effectively in the Korean War. (See illustration facing Page 315.)

RAM DRAG. In thermal jet engines, a quantity defining the **drag** induced by the air required for combustion. It is the product of the mass flow and flight velocity divided by the acceleration of gravity.

RAM EFFECT. The increased air pressure in a jet engine diffuser or in the manifold of a piston engine, due to **ram**.

RAM ENGINE. Ramjet.

RAM PRESSURE. The dynamic pressure or pressure at the inlet of an air-breathing engine resulting from its velocity through the air. It is the function of the air inlet and diffuser to decelerate the air entering the engine, and transform a large portion of the kinetic energy of the air into a pressure rise.

RAM ROCKET. (1) A **rocket motor** mounted coaxially in the open front end of a **ramjet**, used to provide thrust at low speeds and to ignite the ramjet's fuel. (2) The entire unit or power plant consisting of the ramjet and such a rocket.

RAMJET. A compressor-less jet-propulsion engine which depends for its operation on the air compression accomplished by the forward motion of the engine. Compared with cur-

rent turbojet engines, the ramjet engine offers (in its flight regime) certain advantages: (a) The ramjet can produce a larger thrust per unit of maximum frontal area. (b) Because of the absence of rotating machinery the ramjet engine can produce a larger thrust per unit of engine weight. (c) The ramjet engine can be operated with a higher maximum temperature in its thermodynamic cycle. (See Figure 1 and Figure 2.) There are two types

for thermodynamic computations. The encircled numbers indicate stations at critical points inside the motor where significant changes occur in the flow processes. Between stations 0 and 1 an adiabatic compression occurs, between 1-3 an isentropic compression, between 3-4 a constant area heat-added condition is assumed, and between 4-6 an isentropic expansion occurs. The table below indicates how the thermodynamic parameters

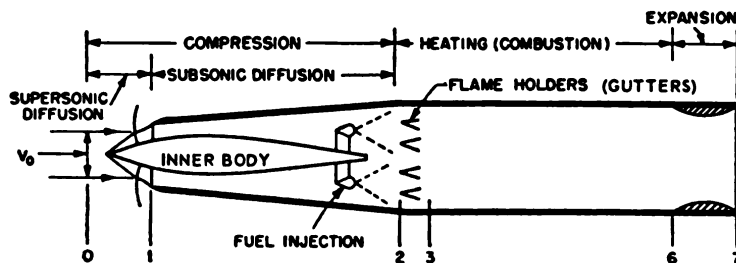


Fig. 1. Schematic arrangement of a supersonic ramjet engine.

of power plants which fall in the ramjet classification. These are: the *athodyd* (Aero THERmODYnamic Duct), a continuous thermal duct, and the *pulsejet* (or resonant jet), an intermittent firing duct motor. Theoretically, there should be no limit to the velocity which can be obtained from a ramjet, but practical heating limitations makes Mach 4 the approximate limit with present structures. At the present time, several U.S. missiles have ramjet sustainer motors. These include: **Talos**, **Triton**, **Navaho**, **Bomarc**, **Hermes B**, and **Gapa**. The ideal ramjet in Figure 3 shows the longitudinal cross-section assumed

change through the motor stations:

PARAMETER	0-a	a-1	1-2	2-3	3-4	4-6
p_t	—	—	k	—	—	k
p	+	+	+	—	—	—
T_t	k	k	k	+	+	k
T	+	+	+	+	+	—
V	—	—	—	+	+	+
C_p	k	k	k	+	+	k
R	k	k	k	k	k	k
ρ	+	+	+	—	—	—
γ	k	k	k	—	—	k
M	—	—	—	—	—	+

NOTE: + = increase, — = decrease, and k = constant

A supersonic ramjet develops thrust according to the following equation (on the next page):

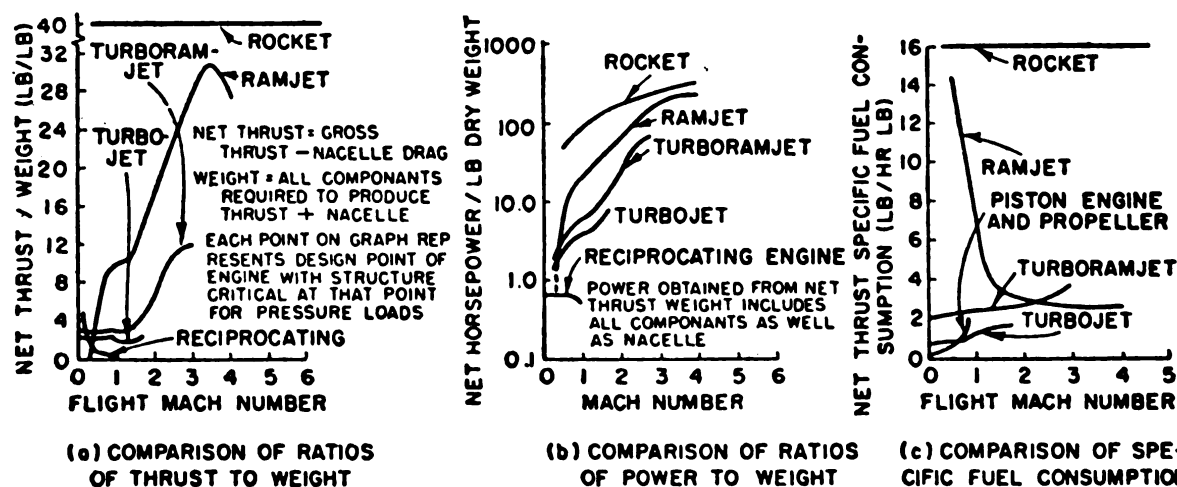


Fig. 2. Comparison of design characteristics of different propulsion engines as a function of the flight Mach number.

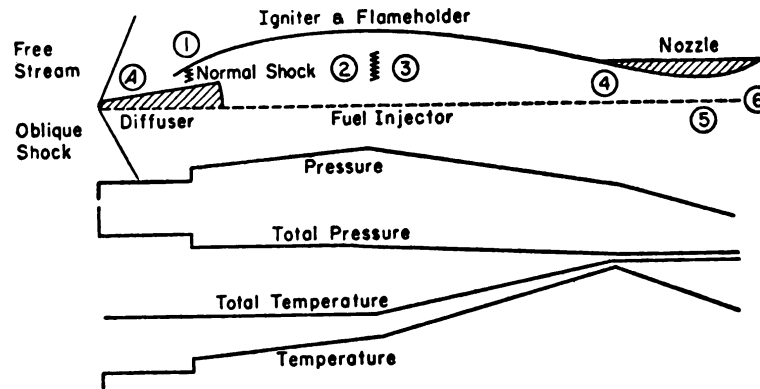


Fig. 3. Ideal ramjet operating conditions.

$$F_t = \rho_0 V_0 S_0 \left[\left(1 + \frac{F}{A} \right) V_6 - V_0 \right] + S_6 (P_6 - P_0)$$

Where F_t is the gross thrust, ρ_0 is the entering air density, V_0 is the inlet velocity, S_0 is the inlet area, $F = F_v + F_p$ is the thrust due to mass flow and pressure differential, A is the internal area upon which the thrust works, V_6 is the exit velocity, S_6 is the exit cross-section, P_6 is the exhaust pressure, and P_0 is the free stream pressure.

Drag of a supersonic ramjet is given by:

$$D = \int_s [(P - P_0)_x + \sigma_x] ds$$

where σ_x is the skin friction stress parallel to

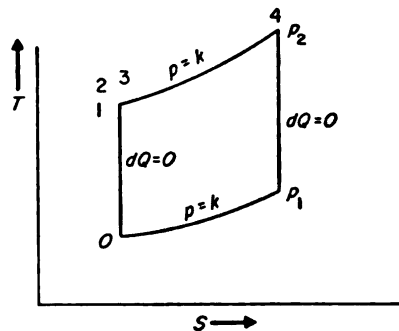


Fig. 4. Ideal ramjet or turbojet cycle.

the free stream direction. Net thrust is $F_n = F_T - D$.

A theoretical S-T diagram showing the thermodynamic cycle of a ramjet appears in Figure 4.

RANDOM NOISE TESTING. A test technique in which the forcing function applied (e.g., a driving signal to a shaker) is a com-

plex wave of varying frequencies and amplitudes—usually, but not always, assumed to have a normal distribution in each octave. The signal may be obtained from an experimental source such as a missile telemetering record or may be made from a signal generator.

RANGE. (1) The distance to any object. In missile operations, many special ranges are used. For anti-aircraft missiles, range may be: horizontal, slant, maximum, minimum, etc. For surface-to-surface missiles, the most common ranges are; horizontal, sea level, maximum, minimum, firing, grid, true or slant. (2) The proving ground itself is known as the "range." (3) In statistics, the difference between extreme values of a variable is known as the "range," i.e., no value can exceed the maximum and minimum defining the range.

RANGE INSTRUMENTATION (AND RANGE SAFETY EQUIPMENT). Equipment used to obtain data from a test and/or to provide for flight termination. Such equipment normally is not part of an operational weapon system but may be included in modified or reduced capacity form. Two categories are used: (a) Active (airborne and ground equipment required). (b) Passive (airborne and ground equipment required).

RANGE MARK. A mark on the cathode ray tube screen which indicates distances from the radar set to objects for which various echoes appear on the screen. It is an electronic fiducial mark projected on the oscilloscope screen for the purpose of comparing ranges.

RANGE SAFETY. Those aspects of field testing relating to protection of life and prop-

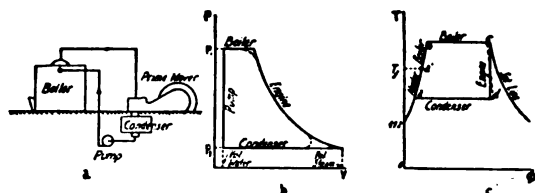
erty from guided missiles when fired at a test range.

RANGE SAFETY EQUIPMENT. Range instrumentation.

RANGE SAFETY SYSTEMS. Systems which gather and present trajectory-position data of an airborne missile, and provide means of terminating missile flight in accordance with range safety regulations at missile test ranges.

RANGE, SLANT. (1) Line-of-sight distance from measuring point to target, especially an aerial target. (2) The direct distance between an explosion and any given point.

RANKINE CYCLE. Rankine's modification of the **Carnot cycle** is the basis of the modern steam plant cycle, even though the Rankine cycle itself has been modified and changed with the passing of time. The elements of the Rankine vapor cycle are shown in Fig. (a).



It consists essentially of a boiler which receives feed water from a pump, a primer mover to expand the steam adiabatically, a condenser to receive the exhaust steam from the engine and reduce it to water, and a pump to overcome the pressure difference between boiler and condenser. Figs. (b) and (c) show this cycle on the pressure-volume and temperature-entropy planes. While illustrated by a steam cycle, the Rankine cycle is any temperature-entropy relationship corresponding to that shown in (c).

RANKINE-HUGONIOT RELATION. In supersonic aero thermodynamics, a mathematical relationship between pressure and density through (i.e., before and after) a normal shock wave. Four forms of this relation appear below:

$$\begin{aligned} \frac{p_1}{p_0} &= \frac{(\gamma + 1)p_1 - (\gamma - 1)p_0}{(\gamma + 1)p_0 - (\gamma - 1)p_1} \\ &= \frac{(\gamma + 1)V_0 - (\gamma - 1)V_1}{(\gamma + 1)V_1 - (\gamma - 1)V_0} \end{aligned}$$

$$\frac{V_0}{V_1} = \frac{\rho_1}{\rho_0} = \frac{(\gamma + 1)p_1 + (\gamma - 1)p_0}{(\gamma + 1)p_0 + (\gamma - 1)p_1}$$

$$\frac{p_1 - p_0}{p_0} = \frac{p_1}{p_0} - 1 = \frac{2\gamma(p_1 - p_0)}{(\gamma + 1)p_0 - (\gamma - 1)p_1}$$

$$\frac{\rho_1 - \rho_0}{\rho_0} = \frac{\rho_1}{\rho_0} - 1 = \frac{2(p_1 - p_0)}{(\gamma + 1)p_0 + (\gamma - 1)p_1}$$

where p is pressure, γ is the ratio of specific heats, ρ is density and V is volume.

RANKINE SCALE. Temperature scales.

RAPID AUTOMATIC CHECKOUT EQUIPMENT (RACE). A system of missile checkout developed by the Microwave Division of Sperry Gyroscope Company. It uses a computer type arrangement to find faults and deliver a punched card identifying the trouble. A card filed maintenance procedure is also provided to assist using personnel in correcting the trouble.

RASCAL. The U.S. Air Force air-to-surface missile designed to be dropped from the bomb a B47 aircraft. It is intended to be released outside the defense perimeter, allowing the mother aircraft to escape while the missile continued on into the target. It was officially designated as the GAM-63. Development was carried out at Holloman Air Force Base, New Mexico, beginning in the late 1940's. (See **missile, guided**.) (See also illustration facing Page 315.)

RASTER. In television, a predetermined pattern of scanning lines which provides substantially uniform coverage of an area.

RAT. (1) A U.S. Navy proposal during World War II to use biological guidance of a bomb. The bomb was to be "flown" by a trained rat. (See also **Cat** and **Bat Bombs**.) (2) A U.S. Navy surface-to-underwater unguided missile. Its payload was a homing torpedo.

RATE ACTION. In servomechanisms, a type of control action in which the rate of correction is made in proportion to how fast the condition has gone out of control. It is also termed derivative action.

RATE GYROSCOPE. A universally-suspended gyroscope with a limited degree of freedom, restricted by an elastic suspension. It registers angular velocities and/or accelera-

tions of a missile about its sensitive axis. A rate gyro normally has all but one degree of freedom restrained, either completely or partially. Some types of rate gyros make use of the principle of gyroscopic precession as the source of rate information rather than the precessive force on a restrained axis.

RATING, CONTINUOUS-DUTY. The rating applying to operation for an indefinitely long time.

RATING, INTERMITTENT-DUTY. The specified output rating of a device when operated for specified intervals of time other than continuous duty.

RATIO, AUGMENTED THRUST. Augmented thrust ratio.

RATIOMETER. An electrical instrument which measures the ratio of two electrical currents. It consists of two moving coils mounted on a common shaft and rotating in non-uniform fields. Each current exerts torque on the common shaft proportional to its magnitude, and the resulting shaft movement is proportional to the current ratio.

RATIONAL HORIZON. (1) A plane that passes through the center of the earth, perpendicular to the zenith-nadir axis of an observer. (2) The circle on the **celestial sphere** made by the intersection of the sphere with this plane. (See **celestial horizon**.)

RATO, Rato, or rato. [From "rocket-assisted takeoff."] (1) A takeoff in which a rocket or rockets, commonly of the solid-fuel type, are used to provide additional thrust. Hence, RATO bottle, Rato unit, rato bottle, etc., a rocket so used. (2) A RATO bottle or unit; the complete apparatus on an aircraft, comprising rockets, ignition system, etc., for assisted takeoff. (Cf. **jato**.)

RATO BOTTLE. A rocket motor used especially to assist vehicles or missiles in takeoff, so-called because of its resemblance to a bottle.

RATRACE. A type of radar wave-guide configuration which serves the same purpose as the **magic tee**, but allows the handling of greater power.

RAVEN. (1) Ranging and Velocity Navigation. A system of **loran** proposed for space

travel using the **Doppler effect** of known beacon emissions from four orbiting stations as detected in the space ship. (Four rather than three stations are required for space navigation, since the planar arrangement of earth-fixed loran stations does not exist.) Orbiting stations can be existing planets. The solution of the problem requires machine computation because of the complex combinations of the motions of all bodies involved. (2) A British solid-propellant **booster**. (3) An air-to-surface missile, with hot-gas generator propulsion system, under development by the U.S. Navy.

RAW DATA. Unprocessed test data. For missile performance the term raw data is applied both to the primary records such as punched tapes, oscillograph recordings and undeveloped photographic films, and to lists of uncorrected figures extracted from them. When the processing has been completed, the instrumental and observational corrections applied, and the results presented in a form suitable for interpretation, they are known as *reduced data*. Finally, after the final (checking) corrections have been made, and the results published in their most refined form, in some cases "linearized," the facts and figures are called *final data*.

RAWIN. (1) Wind tracked either by **radar** or **radio direction-finding**. (2) A **radiosonde**, radiosonde balloon, or other specially-equipped balloon used for this purpose. (3) Wind information gathered by means of radar tracking or radio direction-finding of a specially equipped balloon.

RAWINSONDE. A balloon-borne **transponder** which is tracked as it rises, for the purpose of determining wind velocities aloft.

RAY, ALPHA. α -rays.

RAY, BETA. β -rays.

RAY CATHODE. Cathode rays.

RAY, COSMIC. Cosmic rays.

RAY, GAMMA. γ -rays.

RAY, INFRARED. A synonym for **infrared radiation** (see **radiation, infrared**), i.e., for electromagnetic waves in the wavelength region 0.78 to 300 microns. (The upper limit

is often considered to be as high as 1000 microns.)

RAY, ULTRAVIOLET. A synonym for ultraviolet radiation (see **radiation, ultraviolet**) in the wavelength band between x-rays and violet visible light.

RAYDAC. A computer in use at the Naval Air Missile Test Center, Point Mugu, California. It was made by the Raytheon Manufacturing Company, hence the name *RAY*-theon Digital Automatic Computer. The computer is a general purpose, high speed, electronic-digital computer adaptable to data reduction requirements. (See **reduced data**.) Tube count is approximately 5200, plus about 18,000 germanium diodes. This computer operates on a binary system, but can accept and present data in decimal form. It has the following main units: central control, arithmetic unit, external memory and hunt unit, internal memory, output printer, directly connected printer and operator console, and problem unit.

RAYDIST. A form of VHF (very high frequency) **triangulation** used as a navigational aid. The system requires the taking of differences of **Doppler** readings. Raydist is difficult to operate when acceleration rates are high, owing to a mechanical **servo** method utilized in taking phase balances in the system.

RAYLEIGH CRITERION OF RESOLVING POWER. The image of a point object as seen by any optical system is a **diffraction** pattern. The images are commonly said to be resolved when the principal maximum of one pattern falls on the first minimum of the other pattern. For circular optics, this occurs when the angular separation of the point objects as seen from the objective lens of the system is

$$\phi = \frac{1.22\lambda}{a}$$

Here λ is the wavelength of the light and a is the diameter of the objective lens. (See Robertson, *Introduction to Optics*, Fourth Ed., pages 207 ff.)

RAYLEIGH DISTRIBUTION. A mathematical statement of the distribution of random variables which occur often in nature

RAYLEIGH-RITZ METHOD. A variational principle for the solution of the eigenvalue equation $A\psi = \gamma B\psi$ (A, B operators) based on taking as a trial function a linear combination of a complete set of functions, with coefficients which are to be varied to give the correct solution. It is used in aeroelasticity for computation of **mode** shapes and frequencies.

RAZON. A gravity-powered bomb developed by the United States during World War II. It was of the **Azon** type, but could be steered in range as well as in azimuth. It was also called the VB-3. (See also **Tarzon**.)

Rb. Rubidium.

RC-2. A type of Bowen ribbon-frame camera having a picture speed of 30-180 frames per second. Normally two or more of the cameras are used in pairs to obtain trajectory data by photogrammetry. The camera produces long narrow frames on 5½ inch wide Super XX aerographic-base film. The film moves at a uniform rate of 2.3 feet per second independently of the frame speed. As the exposure rate increases, the height of the frame decreases. Exposed frames have heights of 0.90, 0.45, 0.30, and 0.15 inches for exposures of 30, 60, 90, and 180 frames per second respectively. Lenses of 5, 7, 10, 12 and 24 inch focal length are available. The camera is usually pedestal-mounted on a four wheel dolly. Its mount has three axes of rotation, allowing rotation through 360 degrees in azimuth, elevation from -2 to +20 degrees and roll from -20 to +90 degrees. The timing system of the camera consists of a neon bulb, flashing at a rate of 1000 cycles per second and producing a coded record along the edge of the film.

RC CONSTANT. Time constant.

RC NETWORK. An electrical network of resistors and capacitors used in circuit design for capacitive-differential systems. Frequently the circuit time constant is such as to reduce the transient effect on the total response, and the circuit response is an essentially steady state.

RCM. Radar countermeasures.

RDB. Research and Development Board.

RDF. Radio direction-finder.

Re. Rhenium.

REAC. Reeves Electronic Analog Computer.

REACTANCE. The imaginary part of impedance, as expressed by the relationship $Z = R + jX$, where Z is impedance, R is resistance, j is the square root of -1 , and X is the reactance. In an electric circuit, the reactance is made up of **inductance** and **capacitance**.

REACTANCE, ACOUSTICAL. The imaginary part of the **acoustical impedance**. The unit is the acoustical ohm.

REACTANCE, ELECTRICAL. In an electrical system the imaginary part of the electrical **impedance**. The unit is the abohm.

REACTANCE, INDUCTIVE. Reactance due to the **inductance** of a coil or other part in an alternating current circuit. Inductive reactance is measured in ohms, and is equal to the inductance in henrys multiplied by the frequency in cycles and by the number 2π . Inductive reactance therefore increases with frequency.

REACTANCE, MECHANICAL RECTILINEAL (MECHANICAL REACTANCE). The imaginary part of the **mechanical rectilinear impedance**. The unit is the mechanical ohm.

REACTANCE, MECHANICAL ROTATIONAL (ROTATIONAL REACTANCE). The imaginary part of the mechanical rotational **impedance**. The unit is the rotational ohm.

REACTANT RATIO. The ratio of the weight of flow of oxidizer to fuel in a rocket motor.

REACTION. (1) In general, a response such as the equal and opposite force which, according to the **Newton Third Law of Motion**, results when a force is applied to a material system. Specifically, the force exerted by the supports or bearings on a loaded mechanical system. (2) A term sometimes used for regeneration (see **feedback, positive**). (3) A chemical change. Specifically, a change by which one or more substances are transformed into one or more entirely new substances, the process being accompanied by a change in energy, but not, in most cases, by a change

in the total mass of the system. Radioactive reactions, however, both natural and artificial, do involve a change of the mass of the system, which is accompanied by a release of energy, opposite in sign to the change in mass, and equal to its magnitude multiplied by the square of the velocity of light.

REACTION BALANCE. A **thrust meter** using a balance to measure the thrust of a rocket or jet engine.

REACTION ENGINE, OR REACTION MOTOR. An engine or motor that develops thrust by its reaction to a substance ejected from it; specifically, an engine that ejects a jet or stream of gases created by the burning of fuel within itself. A reaction engine operates in accordance with the third of the Newtonian laws of motion, i.e., to every action (force) there is an equal and opposite reaction. Rocket engines and jet engines are reaction engines. (See **jet engine, rocket engine**.)

REACTION PROPULSION. Propulsion by means of reaction to a jet of gas or fluid projected rearward, as by a **jet engine** or **rocket engine**.

REACTION TIME. The time interval between a command to **launch** and the actual launch, considered to be an attribute of a weapon or weapon system.

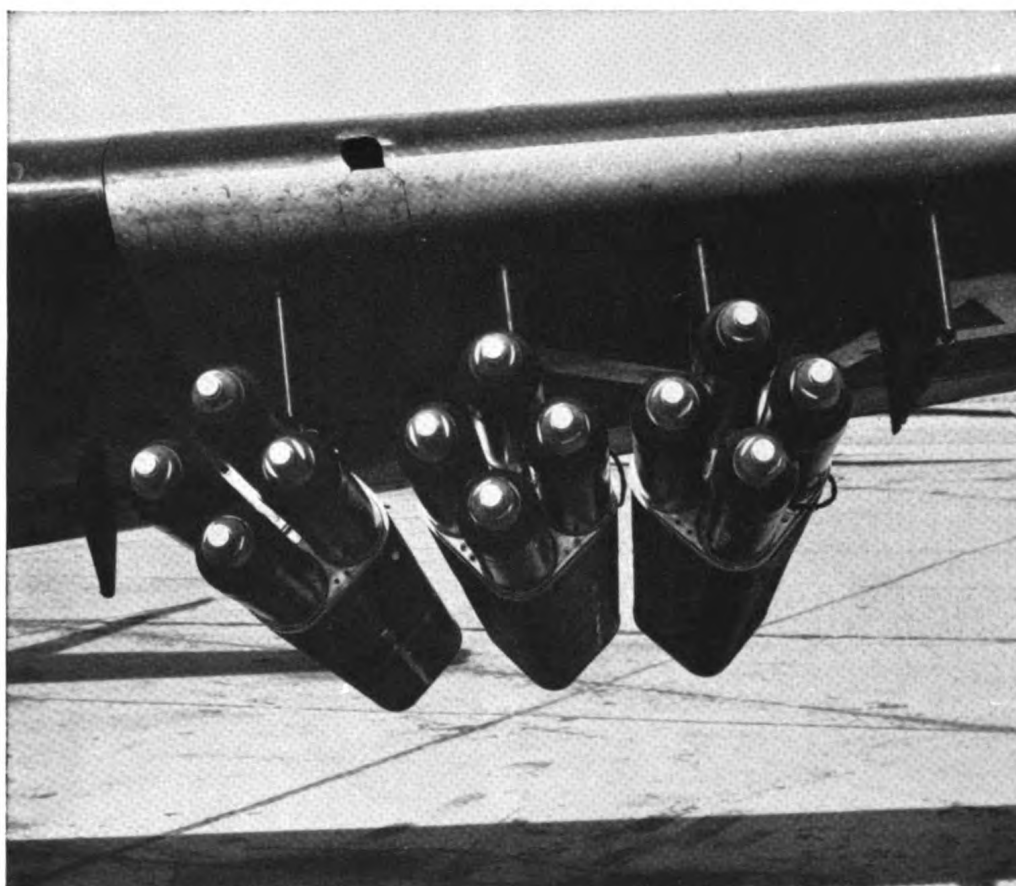
REACTION TURBINE. A turbine which develops its power by the use of a high-pressure, low-velocity gas flow through the rotor blades. The pressure energy is converted to kinetic energy within the rotor blade passages.

REACTOR. (1) A nuclear reactor. (See **reactor, nuclear**.) (2) A device used to introduce **reactance** into a system.

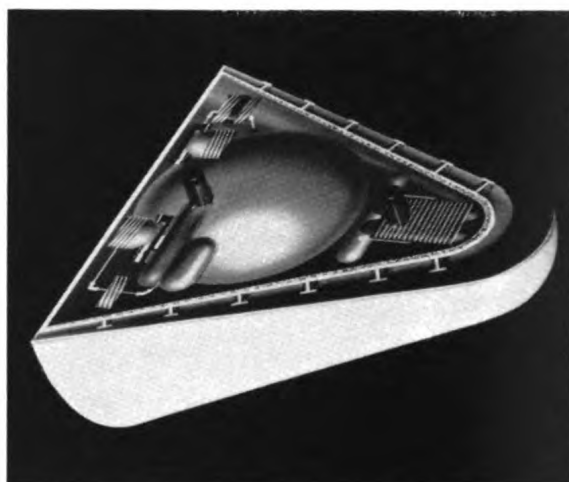
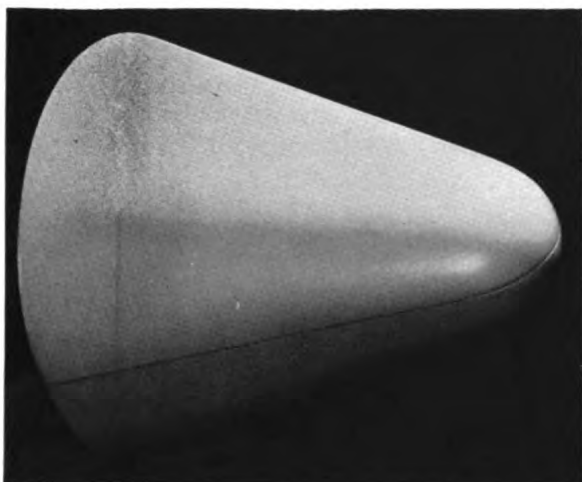
REACTOR, ATOMIC. A device designed to maintain a controlled nuclear chain reaction.

REACTOR, BREEDER. A nuclear reactor (see **reactor, nuclear**) used primarily for **breeding**.

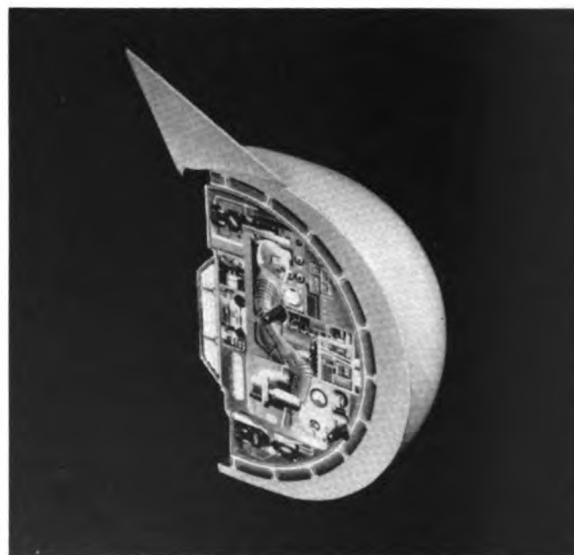
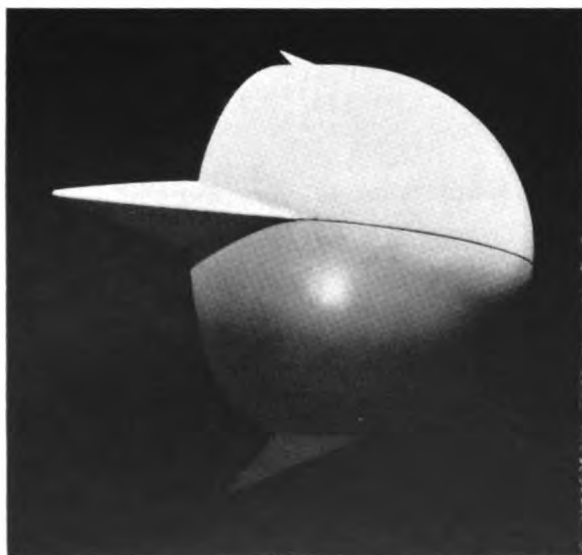
REACTOR, HETEROGENEOUS. A nuclear reactor (see **reactor, nuclear**) in which the fissionable material and moderator are arranged as discrete bodies (usually according to a regular pattern) of such dimensions that a nonhomogeneous medium is presented to the neutrons: (cf. **reactor, homogeneous**.)



The new rocket has folding fins which permit a plane to carry four times the number of the World War II high velocity altitude rocket. The ZUNI launcher, mounted on the plane wing, holds four rockets and is used for transporting and storing the rocket as well as launching it. (*U.S. Navy Photograph*)



An artist's sketch of the BALLISTIC CONE, designed for a possible space vehicle of the future. (*NASA Photograph*)



An artist's sketch of the MANNED HEMISPHERE, designed for a possible space vehicle of the future. (*NASA Photograph*)

REACTOR, HIGH FLUX. A nuclear reactor (see **reactor, nuclear**) designed to operate with high neutron flux. Since a high flux results from a high rate of fission per unit volume, a high-flux reactor operates at high power density.

REACTOR HOMOGENEOUS. A nuclear reactor (see **reactor, nuclear**) in which the fissionable material and moderator (if used) are combined in a mixture such that an effectively homogeneous medium is presented to the neutrons. Such a mixture is represented either by a solution of fuel in the moderator or by discrete particles having dimensions small in comparison with the neutron **mean free path**: (Cf. **reactor, heterogeneous**).

REACTOR, NUCLEAR. A nuclear reactor is a device in which nuclear fission may be sustained in a self-supporting chain reaction. The terms pile and reactor have been used interchangeably, with reactor now becoming more common. These terms usually are applied to systems in which the reactions occur at a controlled rate, but they have also been applied to bombs. This discussion is restricted to the case of controlled reactors. The first nuclear reactor was constructed in 1942 as a first step toward the development of the fission atomic bomb.

The fission process of primary concern in controlled nuclear reactors occurs when an appropriate nucleus such as that of uranium-233, uranium-235, uranium-238, or plutonium-239 captures a **neutron** and then splits into two lighter nuclei (primary fission products) with the release of energy. At the same time, two or three neutrons are emitted, on the average. It is easily seen that a self-sustaining chain of fissions is possible if at least one neutron from each fission can be made to induce another fission. Since the fission of approximately 1 gram of uranium-235 per day yields approximately 1000 kilowatts of power, it is also clear that nuclear reactors represent potentially important energy sources for the world. They also serve other purposes, such as research and development, and the production of fissionable material. The characteristics of these types of reactors, and the functional parts of the individual reactor, can be understood quite readily from consideration of the fission reaction.

The various kinds of atoms (or nuclides) differ in their fission reactions, particularly

in the speeds of the neutrons which cause them to undergo fission. Uranium-235 (which constitutes 0.72% of naturally-occurring uranium) can be split either by slow (thermal) neutrons with energies of about 0.03 electron-volts, or fast neutrons with energies exceeding 1000 electron-volts. Uranium-238, which constitutes about 99.28% of naturally-occurring uranium (there is a very small proportion of a third isotope, which is unimportant in the present discussion) can be split only by fast neutrons. While other agencies than neutrons (e.g., **gamma rays**) can induce fission, and while other nuclides than these undergo fission, these two uranium isotopes are found in most nuclear reactors.

It was stated above that during the average atomic fission two or three neutrons are emitted, and that for the self-sustaining chain of fissions at least one neutron from each fission must induce another fission. If the number of neutrons causing fission in each generation is greater than one, then the rate at which fissions occur will tend to increase, and the chain reaction will continue. There are various conditions that determine the proportion of neutrons that are useful in causing fissions, and these conditions must be considered in obtaining a neutron multiplication factor greater than 1. These conditions are neutron energies, neutron non-fission capture, and neutron escape from the nuclear reactor.

Neutrons are "slowed-down" (that is, they lose energy) when they undergo elastic collisions. Since slow neutrons, as well as intermediate or fast neutrons, and with greater probability, cause fission of uranium-235 atoms, then the suitable use in a nuclear reactor of materials capable of the elastic scattering of neutrons will increase the proportion of slow neutrons, and will therefore increase the rate at which uranium-235 atoms undergo fission. (In fact, they make practicable the design of a "slow" reactor.) Substances used for this purpose (i.e., slowing of neutrons by elastic scattering) are called moderators. Good moderators are water (particularly heavy water), beryllium, and especially carbon; a good moderator reduces the speed of neutrons in a small number of elastic collisions, but does not absorb them to any great extent. On the other hand, many atoms absorb neutrons. For example, atoms of uranium-238 absorb neutrons (provided they are not fast enough to cause fission of uranium-

238) to form uranium-239, which undergoes two successive **beta-disintegrations** to form plutonium-239. This result is not necessarily undesirable, since some reactors are operated primarily to produce this fissionable material, but the process does not contribute to sustaining the chain reaction. Since the latter, with slow neutrons, requires uranium-235 and is retarded by capture of neutrons by uranium-238 it follows that any of the processes whereby the proportion of uranium-235 in naturally occurring uranium can be increased will increase the multiplication factor of a nuclear reactor, not only by providing more uranium-235 to undergo fission with slow neutrons, but also by reducing the uranium-238 that captures them without undergoing fission. It also follows that reactor design for efficient neutron utilization requires a sufficient volume and a suitable geometric design so that the ratio of neutrons escaping from its boundaries is sufficiently low. The suitable use of reflectors also contributes to retarding the escape of neutrons from the nuclear reactor. Still another consideration is the nonfission capture of neutrons by other materials than the uranium-238 cited above. Such materials may be (1) impurities in the moderator, which is therefore made as pure as possible; (2) structural elements of the nuclear reactor, which are therefore made of materials with a low capture cross-section (i.e., probability) for neutrons; (3) fission products of the nuclear reaction, which accumulate as the fission process continues, and which require reprocessing of the nuclear fuel (in this case, the uranium-235) long before it has been all used, and (4) the coolant. The coolant is a medium circulated through the nuclear reactor to remove the large quantities of heat formed. In a power reactor, the coolant transfers this heat to a system utilizing it, and thus carries out the primary purpose of the installation; in other reactors the coolant is used to prevent overheating; but in any case the same requirements of low capture cross section for neutrons applies to the coolant. In addition, the coolant must be able to withstand high temperatures and the action of neutrons (as in fact must the other parts of the nuclear reactor). Common coolants are light and heavy water, air, carbon dioxide, liquid sodium and some other liquid metals—the water is often used under pressure and should be of high purity. It should be added that in some cases

the coolant is the moderator. (Certain organic substances, such as biphenyl and its isopropyl derivative, have shown promise as coolant-moderators.)

The foregoing discussion has dealt with an enriched uranium reactor from the point of view of the requirements for favoring the fission reaction. Obviously an equal need exists for controlling the reaction, that is, for retarding it if its rate becomes too rapid. This is accomplished by the use of control rods made of material having a high capture cross-section for slow neutrons, such as cadmium or boron steel. These rods are arranged so that their position within the reactor is adjustable. If it is desired to increase the power, the controls are partly removed; to reduce it, they are moved further into the reactor. When shutting down the reactor, the control rods are inserted to a considerable depth; they can then capture so many neutrons that the effective multiplication factor becomes less than 1 and the nuclear chain reaction ceases. As a safety feature, most reactors are provided with controls which become operative automatically at a determined reaction rate or in event of power failure.

There are a few general terms applicable to nuclear reactors that have not been mentioned. The chain reacting region is called the core. The moderator, if present, is distributed within the core, and the coolant (which as stated above, may be the moderator) circulates within the core. The entire reactor assembly is surrounded by many feet of suitable shielding to attenuate the intense radiation which accompanies the fission reaction.

One other general term is critical size. The critical size of a uranium-moderator system is defined as the size for which the number of neutrons produced in the fission process just balances those lost by escape and by capture. The critical size is not a constant, but depends on the isotopic composition of the uranium, the proportion of moderator, and the presence of various substances causing parasitic capture of neutrons. If a system is smaller than the critical size, neutrons are lost at a greater rate than they are replenished by fission, and so a self-sustaining, chain reaction will be impossible. It is essential, therefore, that the size of the uranium-moderator lattice should be larger than the critical value if the fission chain is to be maintained.

The various classifications of nuclear reac-

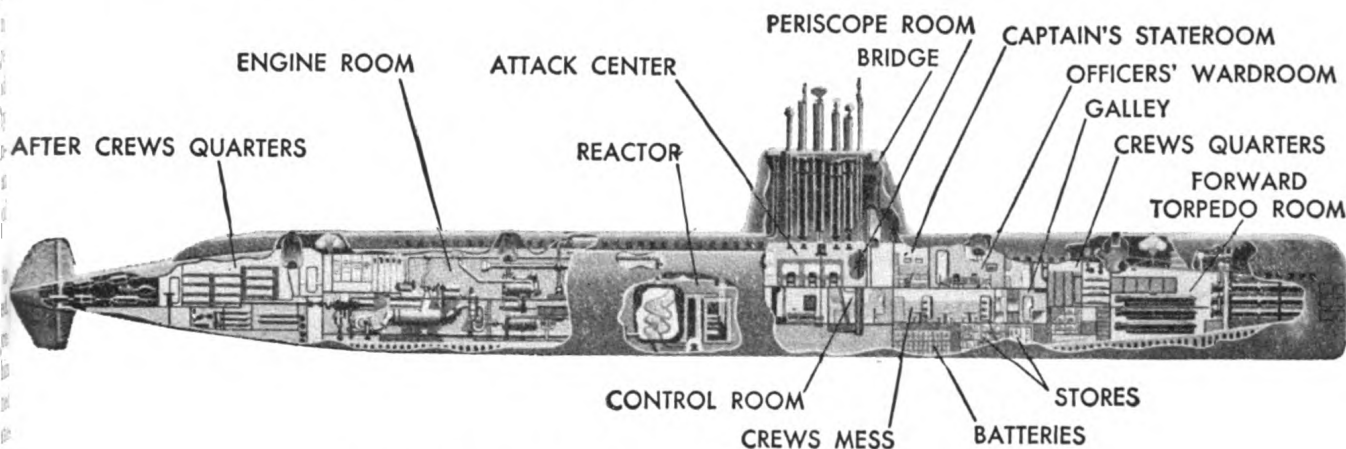
tors are based on (1) the type and arrangement of fissionable material, the coolant and the moderator; (2) the energy (speed) of the neutrons sustaining the reaction; and (3) the purpose of the reactor. The fissionable material (called the fuel) may be natural uranium, natural uranium enriched with uranium-235 (up to 100%), plutonium-239 and uranium-233. The last two fuels are produced in reactors from uranium-238 and thorium-233, respectively. In heterogeneous reactors, the fuel is solid, and is fixed in a regular lattice within the moderator. In homogeneous reactors, the fuel and moderator are mixed intimately as a solution, which can be aqueous or metallic, a molten salt or a slurry.

Another term applied to reactors is the word "bare." A bare reactor operates with-

volts). Fast reactors do not have moderators.

It is also possible to construct combination-type nuclear reactors. Such a type is exemplified by the slow-fast reactor, which is in operation at Argonne National Laboratory on an experimental basis. This is a zero power unit used to study principles of power reactor operation, and designed for rapid exchangeability of parts.

It is really a reactor within a reactor. In the center of a 5-foot diameter steel tank is a fast reactor section containing 49 enriched uranium fuel assemblies in a 2-foot square section. Surrounding this section is the slow reactor section consisting of normal and enriched uranium fuel elements arranged in a geometric pattern around the fast core and immersed in water.



Drawing of the U.S.S. Nautilus. (Official U.S. Navy Photo.)

out a reflector, which as explained above, reflects back neutrons, and thus reduces the critical size of the reactor assembly.

The types of coolants and moderators were discussed above. The PW reactor uses pressurized water for this purpose. The WB reactor is a water boiler reactor, which commonly uses enriched uranium as fuel and ordinary water as moderator, the fuel being in the form of a solution of uranyl sulfate in the water.

Reactors are further classified according to the energy (or speed) of the neutrons required for fission of the fuel. Thermal reactors use slow or thermal neutrons (energies of about 0.025 electron volts); intermediate reactors use intermediate neutrons (energies from 1 to 1000 electron volts); and fast reactors use fast neutrons (energies above 1000 electron

The nuclear reaction starts in the slow section; the neutrons created pass through the steel wall into the fast section, causing fission in the enriched uranium. A nuclear chain reaction cannot be started or maintained in the fast section unless it is maintained in the slow section. In effect, this combination reactor retains the safety and ease of control of a slow reactor, and the superior nuclear reaction efficiency of the fast reactor.

As stated earlier in this article, many types of nuclear reactors are possible by various combinations of fuels, coolants, and moderators, and their arrangements, by the energy of the neutrons sustaining the reaction, and by construction details. The development of nuclear energy in America, as stated in the article on that subject, has been to construct many types of systems, to determine under

operating conditions which is the most efficient technologically and economically. The same policy has been extended to propulsion systems. Thus the first submarine to be operated by nuclear power, the *U.S.S. Nautilus*, has a pressurized water reactor, while the second U.S. submarine, the *U.S.S. Seawolf*, has a liquid sodium-cooled reactor.

REACTOR, POROUS. A nuclear reactor (see **reactor, nuclear**) composed of a porous material or an aggregate of small particles with coolant or fluid fuel flowing through the pores.

REACTOR, THERMAL. A nuclear reactor (see **reactor, nuclear**) in which fission is induced primarily by neutrons of such energy that they are in substantial thermal equilibrium with the material of the core. 0.025 electron volts (2200 meters per second) which corresponds to the mean energy of neutrons in a Maxwellian distribution at 293°K, often is taken as a representative energy for thermal neutrons, although most thermal reactors actually operate at a higher temperature. A moderator is an essential element of a thermal reactor.

READIED MISSILE. A missile which has been tested, fueled, warmed up, supplied with firing data and prepared in all respects for activation of its **firing sequence**.

READINESS TIME. The length or time required to obtain a stabilized system ready to perform its intended function. (Readiness time includes warm-up time.) The time is measured from the point when the system is unassembled or uninstalled to such time as it can be expected to perform as accurately as at any later time. Maintenance time is excluded from readiness time.

READ-OUT. The means for extracting quantitative information from a device, e.g., elevation angle read-out from a **cinetheodolite** is done by reading a photograph.

READY STORAGE. Missile storage adjacent to the launcher or in such location that it is available to the handling equipment which will place it on the launcher. Tactical storage, testing, and ready storage may conceivably be in a single confined area and comprise one general operation if the circumstances so warrant.

REAL TIME. A term applied to the simulation of a guided missile operation on the same time scale as the actual operation. It is used most frequently in the interpretation of telemetry data which are received from the missile in the form of a complex, frequency-modulated signal. An observer on the ground wishing to see immediately what is occurring within the missile, e.g., for guidance purposes, requires a real-time display of selected data. "Real time" data can be presented by meters, recorders, flashing lights, model simulators, or other equipment.

REBECCA. The code name of the airborne interrogator responder of Rebecca-Eureka, a radar responder beacon system.

RECEIVER, RADIO. A device to detect electromagnetic waves. (See **crystal video receiver, radio receiver, super-regenerative receiver** and **tuned radio frequency receiver**.)

RECEIVER SENSITIVITY. The lower limit of useful signal input to the **receiver** set by the **signal to noise (S/N)** ratio at the output.

RECEPTION, DIVERSITY. **Diversity reception.**

RECIPROCITY THEOREM, ELECTRIC-NETWORK. An equivalence theorem of value in electric network analysis. In an electric network composed of passive bilateral linear impedances, the ratio of an electromotive force introduced in any branch to the current measured in any other branch, called the transfer impedance, is equal in magnitude and phase to the ratio that would be observed if the positions of the electromotive force and the current were interchanged. When altering the location of an electromotive force in a network, the branch into which the electromotive force is to be introduced must be opened, while the branch from which it has been removed must be closed.

RECOMMENDED GROUND ZERO (RGZ). That point, with relation to the earth's surface, where it is recommended that a nuclear detonation take place in order to accomplish the desired effects.

RECONNAISSANCE MISSILE (DRONE). A missile whose main mission is reconnaissance (photographic or electromagnetic surveillance) of the enemy.

RECONNAISSANCE SATELLITE. An Earth **satellite vehicle** having the military mission of reconnaissance, (that is, procurement and transmission of strategic information), particularly over the Earth, but also as a space probe.

RECORDING CHANNEL. One of a number of independent recorders in a recording system or one of two or more independent recording tracks on a recording medium. One or more channels may be used at the same time for covering different ranges of the transmitted frequency band, for multichannel recording, or for control purposes.

RECORDING OPTICAL TRACKING INSTRUMENT (ROTI). An instrument made by the Perkin-Elmer Corporation to photograph and record the position of a moving object in space. The Mark I Roti is a twin telescope "over and under" arrangement. The upper tube is a Newtonian telescope of variable focal length (100-500 inches in steps of 100 inches). The lower telescope is a modified Schmidt type having focal adjustable lengths from 50 to 100 inches in steps of 25 inches. Both telescopes have 16-inch apertures. The mount tracks the object, and records angular positions against time by photographs taken by 2 large size (70mm) cameras—one per telescope. A third camera is required to photograph the azimuth and elevation dials at regular time intervals. Roti Mark II is a newer model, which has radar input for automatic focusing.

RECORDING SYSTEM, MULTITRACK. A recording system which provides two or more recording paths on a medium, which may carry either related or unrelated recordings in common time relationship.

RECOVERY. A generic term covering the means whereby a missile or a valuable part thereof can be recovered for analytical study and/or reuse. (The principal techniques are landing on wheels or a skid strip, lowering by parachute, and recovery of a ruggedized data cassette.)

RECOVERY TIME (OF A RADIATION COUNTER). The minimum time from the start of a counted **pulse** to the instant a succeeding pulse can attain a specific percentage of the maximum value of the counted pulse.

RECRUIT. A small, scaled-down solid-propellant rocket similar to the **Sergeant** rocket.

RECTANGULAR COORDINATES. **Cartesian coordinates** with three mutually perpendicular axes, used for locating the position of a point in space. A convention must be established for the relative arrangement of the three axes. The usual case, which is called a right-handed system, may be described as follows. Calling the axes *OX*, *OY*, *OZ*, choose the *XY*-plane to lie in the plane of the paper with the positive *OX*-axis pointing to the reader's right and the positive *OY*-axis pointing toward the top of the page. The positive *OZ*-axis is then pointing upward from the page toward the reader. If a pair of axes is exchanged, the system becomes left-handed.

RECTANGULAR SCANNING. **Scanning, rectangular.**

RECTIFIER. A device having an asymmetrical conduction characteristic which is used for the conversion of an alternating current into a current having a unidirectional component.

RECTIFIER, CONTACT. A **rectifier** consisting of two different solids in contact, in which rectification is due to greater conductivity across the contact in one direction than in the other.

RECTIFIER, COPPER-OXIDE. A **semiconductor rectifier** utilizing the barrier layer developed between metallic copper and cuprous oxide. The units are low in efficiency, but noted for extremely long life.

RECTIFIER, CRYSTAL. **Rectifier, contact; diode, crystal.**

RECTIFIER, ELECTROLYTIC. **Electrolytic rectifier.**

RECTIFIER, FULL WAVE. A radio tube, selenium rectifier, or other device which rectifies an alternating current in such a way that both halves of each input a-c cycle appear in the pulsating rectified output. A full-wave rectifier tube contains two separate diode sections, one passing current during one alternation, and the other passing current during the opposite half cycle. Bridge rectifier circuits are often used for full-wave rectification.

RECTIFIER, HALF-WAVE. A rectifier which utilizes only half of the input-alternating waveform.

RED-SHIFT. Displacement, toward the red end of the spectrum, of familiar absorption lines in spectra of the light of stars, nebulae, and luminous astronomical objects in general. (See **red shift (gravitational)**; and **red shift (nebulae)**.)

RED SHIFT (GRAVITATIONAL). Consequence of general relativity theory that the periods of identical oscillators at different points depend on the gravitational potentials at those points. The wavelength of a spectral line coming from the sun should thus exceed that of the corresponding line from a source on the earth by the fraction 2.12×10^{-6} .

RED SHIFT (NEBULAE). Displacement toward the red of spectral lines from distant nebulae, usually interpreted as a **Doppler effect** due to their motion away from our galaxy.

RED STAR. In astronomy, one of the coolest types of stars. Temperatures on the surface of these stars are estimated to be 2000°K and less. (See also **blue stars**.)

RED-OUT. A temporary condition in which vision is obscured by a reddishness, or in which objects appear to have a reddish color. This condition, sometimes followed by unconsciousness (not considered a part of the red-out), is caused by the blood rushing to the head. (Cf. **blackout**.)

REDSTONE. A large, surface-to-surface **guided missile** developed by the U.S. Army Ballistic Missile Agency (ABMA) at Redstone Arsenal, Huntsville, Alabama. The missile was built under the direction of Professor Wernher von Braun and other German rocket engineers working for the U.S. Army. Production contract for the weapon was awarded to Chrysler Motor Company of Detroit, Michigan. Published pictures of the missile, released in 1956, showed Professor von Braun, indicating the relative height of a man standing beside a model of the missile. It was apparent that the missile was approximately 70 feet long, and approximately 6 feet in diameter. The rocket was powered by a North American liquid-propellant rocket

burning alcohol and liquid oxygen. The maximum range of the missile is on the order of 200 miles. It is a single stage missile powered by the North American liquid-oxygen-alcohol motor. Guidance system for the Redstone was designed by ABMA and contracted out to the Ford Instrument Company. Airframe was produced by Reynolds Metals Company (the Chrysler Corporation being the prime contractor for production.) The Redstone project came out of the **Hermes C-1** project which was transferred to Redstone Arsenal in 1951. The project was first called URSA, then Major and finally Redstone. In September 1956, a composite multistage missile using a Redstone booster as first stage was fired to a record range of over 3000 miles, and an altitude of more than 600 miles. This was reportedly a three-stage missile with the second and third stages powered by solid propellant rocket clusters designed by the Jet Propulsion Laboratory. The Redstone missile was turned over to Army troops in the early summer of 1958. During its research and development firings the Redstone demonstrated an excellent record of reliability and performance. Its inertial guidance system formed the basis for the system used in the **Jupiter** missile, and its advanced development made the transition to the Jupiter application rapid and economical. The Redstone thrust unit, specially lengthened for more fuel capacity, was used in the Army's successful **Explorer** satellite firings. (See **missile, guided**.) (See also illustration facing Page 346.)

REDUCED MASS. In treating any two-body problem, the absolute coordinate frame in which the laws of motion may be applied is an inertial system, i.e., a system which is not accelerated with respect to the fixed stars. The center of mass system of two bodies, having masses M and m and acted on only by mutual forces, is such an inertial system. When the equations of motion are transformed to center of mass coordinates, it is found that they are identical with equations in a system having its origin fixed at M if the mass m is replaced by the reduced mass, $\mu = Mm/(M + m)$. If $M \gg m$, the reduced mass is closely approximated by M .

REDUCED VELOCITY. In flutter analysis, the ratio of airspeed to oscillation frequency of an aerodynamic surface.

REDUCTION (DATA). In missile data processing, the preparation of reduced data from **raw data** as discussed in the article on that subject.

REDUCTION OF AREA. In a material subjected to stress, the difference between the original cross-sectional area and that of the smallest area at the point of rupture. It is usually stated as a percentage of the original area; and is also termed *contraction of area*. The reduction in area is a useful characteristic for describing the ductility or degree of brittleness of a material.

REDUNDANCY. The employment of multiple devices, structural elements, parts or mechanisms in combination (where each is capable of performing the same function) for the purpose of increasing the probability of occurrence and the reliability of the particular function or operation. It allows the adoption of more than one path in achieving a desired effect.

RE-ENTRY. The return of a missile into the earth's atmosphere. At high speeds the principal re-entry problem arises from frictional heating. As the **Mach number** increases, temperatures due to air friction are sufficient to melt nose cones, unless special shapes and special materials are used. Another re-entry problem arises from the **ionization** in the **shock wave** region. Electron densities approaching those of solid metals are generated by re-entering bodies at hypersonic speeds. It has even been proposed to excite this electron sheath with radio frequency signals, using it as an antenna in order to insure continuous communication with the re-entering body. It has been determined that the best shape for a high Mach number re-entry vehicle is a blunt, or even hemispherical shape. This high-drag, smooth configuration causes the body to slow down rapidly with maximum transfer of energy to the atmosphere.

RE-ENTRY BODY. That portion of a space traversing missile which usefully reenters the atmosphere. In a long-range ballistic missile, the separable re-entry body contains the heat shield, warhead, attitude stabilizing and fuzing equipments needed to: reenter the earth's atmosphere without self-destruction from a very high velocity and altitude; as well

as to reduce the dispersion and explode the warhead.

RE-ENTRY TRAJECTORY. That part of the trajectory of a ballistic missile extending from re-entry to target.

REFERENCE ANGLE. The acute angle between the center line of a radar beam striking a reflecting surface and a line perpendicular to that surface.

REFERENCE AREA. Any arbitrary area on a body taken as a coefficient in equations for determining an aerodynamic force acting upon the body.

REFLECTED WAVE. Wave, reflected.

REFLECTION. When an emission, such as radiation or sound, traveling in one medium encounters a different medium, part of it in general passes on and undergoes **refraction**, while part is reflected. Even water waves exhibit reflection upon meeting an obstacle, and some of the characteristics of the process are conveniently observed by watching surface ripples. In all cases of "regular" reflection, in which the direction of propagation is sharply defined after reflection, the change takes place in accordance with a very simple law, viz., the reflected and incident wave trains travel in directions making equal angles with the normal to the reflecting surface and lie in the same plane with it. These angles are called, respectively, the angle of reflection and the angle of incidence. For normal incidence, both of these angles are zero. Rough surfaces reflect in a multitude of directions, and such reflection is said to be "diffuse." Only part of the emission or of the energy associated with it is reflected; the ratio of that part to the whole incident emission is called the "reflectivity" of the surface.

REFLECTION COEFFICIENT. For plane waves or transmission lines, the ratio of the reflected wave to the incident wave. By extension, the concept is applied to **networks** to express the effect of an **impedance** mismatch. From the general conception, three specific definitions follow: (1) The acoustic reflection coefficient is the ratio of the flow of reflected sound energy to the flow of incident sound energy. (2) For a transition or discontinuity between two transmission media, the reflection coefficient is that which would

be observed at a specified point in one medium if the other medium were match-terminated. (3) The reflection coefficient in a transmission medium is defined as follows: At a given point, and for a given mode of transmission, the ratio of some quantity associated with the reflected wave to the corresponding quantity in the incident wave. The reflection coefficient may be different for different associated quantities, and the chosen quantity should be specified. The "voltage reflection coefficient" is most commonly used, and is defined as the ratio of the complex **electric field strength** (or voltage) of the reflected wave to that of the incident wave.

REFLECTION, DOPPLER. A Doppler radar station system using a single receiver station to measure velocities.

REFLECTION INTERVAL. The time interval between the transmission of a radar pulse or wave and the reception of the reflected wave at the point of transmission.

REFLECTION LOSS. (1) That part of the transmission loss due to the reflection of power at a discontinuity. (2) The ratio in **decibels** of the power incident upon a discontinuity to the difference between the power incident upon and the power reflected from the discontinuity.

REFLECTIVE CODE. Gray code.

REFLECTIVITY. The fraction of the incident **radiant energy** reflected by a surface that is exposed to uniform radiation from a source that fills its field of view.

REFLECTOR. (1) A scattering substance surrounding the core of a nuclear **reactor**, used for the purpose of reducing the loss of neutrons due to leakage, and therefore, making the dimensions of the reactor smaller. Common reflectors are water, graphite and beryllium. (2) A system of wires or metal surfaces placed behind an antenna as a parasitic element to improve its directional characteristics and gain. (See **corner reflector** and **lens**.)

REFLECTOR, CONFUSION. A reflector of electromagnetic radiation used to create echoes for confusion purposes against **radars**, **guided missiles**, and **proximity fuzes**. (See **chaff**; **meaconing**; **rope**; **window**.)

REFLECTOR, CORNER. (1) A reflector (see **reflector** (2)) consisting of two or three mutually-intersecting, conducting surfaces. Corner reflectors may be dihedral or trihedral. Trihedral reflectors may be used as radar targets. (2) A reflector (see **reflector** (2)) which consists of two plane-conducting surfaces set at an angle of 45° to 90° with the driven element on a line bisecting the angle. The reflecting surfaces are not necessarily solid, but can be made from wires spaced about 0.1 wavelength apart. In a given amount of space, the corner reflector gives better directivity than the parabolic reflector.

REFLECTOR, PARABOLIC. A reflector consisting of some form of a paraboloidal mirror. Usually used in conjunction with an antenna.

REFLEX CIRCUIT. A circuit in which the signal is amplified, both before and after detection, in the same amplifier tube or tubes.

REFLEX KLYSTRON. A klystron in which the two resonant circuits of a conventional **klystron** are confined into a single resonant cavity, which now acts also as anode. As an oscillator, the reflex klystron possesses the advantage of having only one tuned circuit to be adjusted. Also it is possible to make small adjustments to the frequency by altering the voltage on the repellent. (The tuning range obtainable in this way is small, of the order of about one per cent.)

REFRACTION. (1) The bending of a ray of light or other radiation as it passes from one medium to another of different **refractive index** (see the **Snell laws**). (2) The variation of the direction of sound transmission due to spatial variation of the wave velocity in the medium.

REFRACTIVE INDEX. The **phase velocity** of radiation in free space divided by the phase velocity of the same radiation in a specified medium. Because of the Snell law, refractive index may also be defined as the ratio of the sine of the **angle of incidence** (*in vacuo*) to the sine of the **angle of refraction**. Because the refractive index of air is only about 1.00029, refractive index is frequently measured with respect to air rather than with respect to free space (vacuum). Excepting a few very special cases (x-rays,

light in metal films) the refractive index is a number greater than unity. A few representative values are $n_{\text{water}} = 1.34$, $n_{\text{glass}} = 1.5$ — 1.9 , $n_{\text{germanium}} = 4.25$ (infrared radiation).

REFRACTORY MATERIALS. Substances having high resistance to heat. Some substances having refractory properties are:

MATERIAL	MELTING POINT
Alumina (Al_2O_3)	1700°C
Beryllia (BeO)	2100°C
Magnesia (MgO)	2200°C
Zirconia (ZrO_2)	2600°C
Thoria (ThO_2)	3000°C
Molybdenum Carbide (MoC)	2600°C
Tungsten Carbide (WC)	2700°C
Titanium Carbide (TiC)	3200°C
"Fiberglas"	
Zirconium Carbide (ZrC)	3500°C
Niobium Carbide (NbC)	3500°C
Chromium Carbide (CrC)	3600°C
Hafnium Carbide (HfC)	3800°C
Tantalum Carbide (TaC)	3800°C
Tantalum Nitride	3900°C
Titanium Nitride	3300°C
Graphite	4000°C

Uncooled rocket motors lined with refractory materials give reliable operation for periods up to 60 seconds or more. Unprotected metals would be melted in a few seconds.

REFRIGERANT. A substance which is suitable as the working medium of a cycle of operations wherein refrigeration is accomplished.

REGENERATIVE OPERATION. (1) A system of combustion chamber cooling in which one of the **propellants** is passed through hollow combustion chamber walls from the rear of the engine forward before introduction of the liquid into the chamber for burning. (2) A method of signal amplification by positive **feedback**, i.e., in an electrical or electronic system, return of an output signal that is in phase with the input to a stage closer to the input. (3) In **automatic control** devices, the feedback of an output signal for use in a comparator in order to minimize control deviations.

REGENERATOR. A device used in combustion systems to preheat incoming air by hot exhaust gases before introducing the air into the **combustion chamber**.

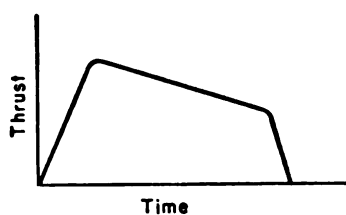
REGION OF INFLUENCE. In supersonic aerodynamics, the zone of disturbed air be-

hind the **Mach wave**. As the velocity of the body increases, the region of influence decreases.

REGISTER. In automatic computers, the storage or recording unit.

REGRESSION OF THE NODES. Satellite elements.

REGRESSIVE BURNING. Burning of a solid propellant rocket grain characterized by a decreasing pressure versus time characteristic. (See figure.) (Cf. **progressive burning**.)



Regressive burning.

REGULATOR (PRESSURE). A device, usually hydraulic or pneumatic, for controlling pressure. The balanced type uses springs or dome-loaded devices, the latter being the most common in missile applications, where their high capacity and independence of constant air input are important advantages.

REGULUS I. A U.S. Navy, pilotless aircraft type surface-to-surface missile capable of submarine launch. It was announced in 1953 after 6 years of development by Chance-Vought for the Bureau of Aeronautics. Its configuration was that of a conventional swept-wing aircraft of about 30-foot span. The missile was first flown at Edwards Air Force Base, California in 1950. It used a turbojet, with two Aerojet General solid-propellant rocket boosters for takeoff. It is about 30 feet in length, about 14,500 pounds in weight. It became operational in 1955-56, and is capable of launch from shore stations or surface ships, and can carry a nuclear warhead. It was also designated SSM-N-8. (See **missile, guided**.) (See also illustration facing Page 347.)

REGULUS II. An improved version of the **Regulus I**. Its range was designed to be about 1000 miles. Its dimensions were 57 feet in length, 20 feet in wingspan. It was de-

signed for shore, ship or submarine launching. On 10 December 1957, the U.S. Navy flew a Regulus II at a maximum speed of 1200 miles per hour during a 30-minute test flight after which the missile was successfully recovered. It was powered by a General Electric turbojet, with two solid propellant boosters for takeoff. It is expected to be operational with the fleet in 1958. Its official designation is SSM-N-9. (See *missile, guided*.) (Illustration facing Page 347.)

REGURGITATION. In ramjet operation, the sudden movement of the shock wave that is normally within the air intake, to a point in front of the nose of the engine. This causes the formation of a normal shock wave and spillover around the engine, with an accompanying lowering of the operating efficiency.

RELATIVE AZIMUTH ANGLE. An azimuth angle measured from directly ahead of a ship or aircraft to the right, usually in degrees from 0 to 360.

RELATIVE BEARING. (1) Bearing, especially as measured from some reference point or line other than true or magnetic north. (2) The bearing of an object or point measured from directly ahead of a ship or aircraft to the right, usually in degrees from 0 to 360.

RELATIVE HUMIDITY. The fraction or percentage of the actual vapor pressure of the water vapor contained in the atmosphere at a given temperature, to the maximum or saturated vapor pressure of water vapor at the same temperature.

RELATIVE VELOCITY. Velocity, relative.

RELATIVE WIND. The vector velocity of the air with reference to a body in it. Measurements of the relative wind are properly made some distance from the body, so that its disturbing effect upon the flow is negligible.

RELATIVISTIC MASS EQUATION. The equation

$$m = m_0(1 - v^2/c^2)^{-1/2},$$

where m is the relativistic mass of a body or particle of rest mass m_0 , when its velocity relative to the observer is v , and c is the velocity of light.

RELATIVITY. A principle that postulates the equivalence of the description of the universe, in terms of physical laws, by various observers, or for various frames of reference. A theory that utilizes such a principle is called a relativity theory.

RELATIVITY THEORY, GENERAL. Generalization of special relativity theory (see *relativity theory, special*) to relate the measurements of observers who are accelerated relative to each other and hence no longer in an inertial system. The fundamental postulate is the principle of equivalence from which may be deduced the equality of the inertial mass and gravitational mass of a system. In addition, one postulates a generalized relativity principle, that the equations of mechanics have the same form for all observers, whether accelerated or not. The essential equivalence between an externally applied "real" gravitational field and the "fictitious" inertial forces experienced by an accelerated observer is introduced by representing the motion of a system in Riemannian space of which the metric $g_{\mu\nu}$ represents the gravitational potentials, whether these be "real" or "fictitious." A test particle is then supposed to move along a geodesic in this space. The values of the $g_{\mu\nu}$ corresponding to a particular distribution of matter are given by the solution of the Einstein law of gravitation. For a point mass, the Schwarzschild solution of these equations leads directly to verified predictions of the bending of light in a gravitational field and the precession of the perihelion of Mercury. (Although electromagnetic phenomena have not been incorporated into general relativity theory in a completely satisfactory manner, the motion of a light ray is computed on the assumption that it moves along a null-geodesic, the natural generalization of the null-cone of Minkowski space.) In addition, the theory describes the gravitational red shift of light moving from one point to another in a gravitational field.

RELATIVITY THEORY, SPECIAL. Theory developed by Einstein based on the hypothesis that the velocity of light is the same as measured by any one of a set of observers moving with constant relative velocity. According to Newtonian theory and the Galilean transformation the mechanical motion of an object with respect to an inertial system could be

predicted from a knowledge of the forces acting on it and the initial conditions, independently of any knowledge of the motion of the inertial system itself. Einstein extended this to optical phenomena, postulating that these also could be described without knowing the velocity of the laboratory with respect to the rest of the universe. The null result of the Michelson-Morley experiment and of other attempts to measure the velocity of the laboratory relative to the ether (see **ether hypothesis**) was then interpreted as an immediate consequence of a fundamental principle of relativity, that the equations of electrodynamics have the same form in all systems in which the equations of mechanics are valid. From this principle, and the constancy of the velocity of light, it is possible to deduce the Lorentz transformation (appropriately modified in its interpretation so as to ignore the ether and to relate the observations of two observers moving with constant relative velocity). Since the Maxwell equations are covariant under this transformation but the equations of Newtonian mechanics are not, one is led to a modified description of the mechanics of particles which is in accord with the relativity principle. This description is indistinguishable from the Newtonian theory for systems in which all relative velocities are small compared with that of light, except that in this limit it also predicts that when a mass m_0 is annihilated an amount of energy $E = m_0 c^2$ is released. In the more general case the mass of a particle is given by $m = \gamma m_0$ where m_0 is its rest-mass and $\gamma = (1 - \beta^2)^{-1/2}$, with $\beta = v/c$, v being the velocity of the particle relative to the observer, and the expansion of $E = mc^2$ in powers of β then yields $E = m_0 c^2 + \frac{1}{2} m_0 v^2 + \dots$ the second term being the kinetic energy of the particle in Newtonian mechanics. The momentum of a particle then appears as mv , and the rate of change of this expression with respect to the time is equal to the force acting on the particle. The relation between the energy E and momentum p of a free particle then becomes $E^2 = p^2 c^2 + m_0^2 c^4$.

In addition to leading to such well-verified conclusions, special relativity theory was able to yield also the few valid consequences of the ether hypothesis. It provided the first verification of the Mach principle by its insistence on the rôle of the observer in the description of phenomena which the observer measures (cf. **Quantum mechanics**) and pointed out

that even the simultaneity of two events at different positions is not an intrinsic property of those events, but depends also on the motion of the observer who is recording them. This result emerges from Einstein's re-interpretation of the Lorentz transformation, referred to above, and is related to the consequent re-interpretation of the Fitzgerald factor and to the relativistic slowing of clocks.

The formal identification of a Lorentz transformation with a rotation in Minkowski space provides a basis for representing the equations of relativistic mechanics as relations between four-vectors analogous to representation of the non-relativistic equations as relations between vectors. In the same way that the latter representation ensures that the form of the equations shall be independent of the particular directions in which the chosen set of orthogonal axes happens to point, so the Minkowski representation ensures that the equations of relativistic mechanics shall be independent of which Lorentz observer is involved. All observers moving with constant relative velocity thus use equations of the same form to describe the optical and mechanical phenomena which they measure.

RELAXATION OSCILLATOR. (1) Generally, an oscillator having a decidedly non-sinusoidal output, resulting from abrupt transitions from one unstable state to another. (2) An oscillator in which the frequency is controlled by the charge or discharge of an inductor or capacitor through a resistor. (3) A multi-vibrator oscillator circuit employing two tubes (or a double section tube) with resistance-capacitance coupling between the tubes to feed the output back and forth between them. Used in television circuits to generate sweep voltages for cathode-ray tubes.

RELAXATION TIME. In many material phenomena, the response to an abrupt change is often a time-measurable approach to equilibrium, frequently exponential. Examples are: (1) An abrupt change of **magnetizing force** usually does not produce an instantaneous, corresponding change in magnetic induction, but the new value is approached over a period of time. The time constant involved in such a phenomenon is often called **relaxation time**. (2) A case closely related to the foregoing is that of a crystal in which all the spins are aligned by a magnetic field, which is

then removed. (3) The time necessary for a stress in a Maxwellian fluid at rest to decay to $1/e = 0.368$ of its initial value. The apparent solidification of vitreous materials is due to a very rapid increase in the relaxation time. (4) The time for which an electron may travel in a metal before it is scattered, and loses its momentum.

RELAY. (1) An electromagnetic switch employing an armature to open or close contactors. A small current through the coil actuating the armature thus can control a heavy duty circuit at the contactors. (2) A device to receive and retransmit a signal from a source to a terminus otherwise too distant to receive the signal.

RELAY TYPE SERVOMECHANISM. A **servomechanism** in which the full power of the motive source is applied as soon as the error is large enough to operate a relay.

RELIABILITY. (1) The quality of a device or its components which permits unfailing performance in all of the environments of operations. (2) The probability of a device performing its purpose adequately for the period of time intended under the operating conditions encountered. If the product rule is used the *over-all reliability* is based on the product of the individual reliabilities of each element: e.g., 100 components (if independent) with a 99% reliability each will have an over-all reliability of 36.5%.

Overall Reliability = $q_1 \cdot q_2 \cdot q_3 \cdot q_4 \cdot \dots \cdot q_N$
where $q_1 = (1 - p_1)^n$, etc.

P_1 is the probability of component failure at some random time, q_1 is the probability that component will not fail at this random time, n is the number of such components in series, N is the number of different classes of independent components in series. (See **functional reliability**.)

RELIABILITY, CUMULATIVE. The concept of establishing reliability by weighting or use of the learning curve; the heaviest emphasis is on the last missile or system tested (i.e., the one with the most advanced state of development, the most learning, etc.) In one approach the weights assigned the reliability of successive articles are as follows:

$$R_c = \frac{\sqrt{1} R_1 + \sqrt{2} R_2 + \sqrt{3} R_3 + \dots + \sqrt{n} R_n}{\sqrt{1} + \sqrt{2} + \sqrt{3} + \dots + \sqrt{n}}$$

where R_c is the cumulative reliability
 $R_1 \cdot \dots \cdot R_n$ are the reliabilities of each missile.

RELIABILITY, FUNCTIONAL. The probability that all components, units, or major units in a system will function within their specified operating tolerances for a specified length of time and under specified environments.

RELIEF VALVE. Valve, relief.

RELUCTANCE. The resistance of a material to magnetic flow; the reciprocal of **permeance**.

REMAINING MASS. The mass of that part of a rocket missile, rocket vehicle, or its payload that remains after the fuel or fuels have been exhausted, and after fall-away sections or parts have been cast off. (See **mass ratio**.)

REMOTE VELOCITY. The velocity of an object taken as a whole relative to the surrounding fluid, as distinguished from the local velocity of any of its parts.

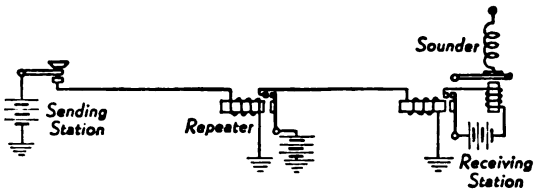
REMANENCE. The **residual induction** B_r when the **magnetizing field** is reduced to zero from a value sufficient to saturate the material. (See **hysteresis**.)

REMOTE CONTROL. A system or method of controlling any equipment or assembly, such as a radio transmitter, whereby the control functions are performed from a distance, electrically, over intervening wire- or radio-circuits.

REPEATABILITY. A measure of **deviation** of test results from their mean value, all determinations being carried out by one operator without change of apparatus in those cases where the manner of handling apparatus can alter results.

REPEATER. (1) A **repeating coil**. (2) A device for receiving, amplifying, and retransmitting a signal or wave. The application may involve telephone or telegraph lines, waveguides, or a complete radio receiver-transmitter (in which case reception is on one frequency and transmission on another,

to prevent interference). In communicating over long lines the electrical pulses gradually become attenuated and often distorted so they must be built back to sufficient amplitude and correct shape to satisfactorily operate the receiving equipment. The restoration of these attenuated signals is the function of repeaters. In telegraph circuits various mechanical re-



peaters are often used. One of the simplest is shown in the diagram. In this simple form communication is possible in one direction only, for the receiving station cannot break the circuit, as it would have to do in order to insert a key. A repeater station, more complicated than that diagrammed, can be installed to provide two-way telegraphy. Two repeaters having holding coils, and extra batteries are required in this system. These, however, do not restore the original spacing and shape of the pulses and the resulting signals may still give false operation of the receiving devices. In order to overcome this fault regenerative repeaters are used on many telegraph circuits, particularly on teletype or printing circuits. Moreover, in **digital** electronic **computers**, extensive use is made of fast-acting repeaters.

REPEATER JAMMER. Jammer, repeater.

REPEATING COIL. A transformer (usually with a 1:1 ratio) employed in telephone lines to prevent conductive coupling between two line-sections.

REPRODUCIBILITY. (1) In instrument work, the exactness with which a measurement of a given value can be duplicated. (2) In manufacturing, the degree to which parts, assemblies, etc., can be duplicated.

REPULSIVE FORCES. Forces between bodies which tend to move them apart. The existence of such forces between molecules is shown by their collision diameters and similar properties; while in the case of crystals these forces, in equilibrium with forces of attraction, result in the formation of a stable ionic system.

REQUIREMENT, OPERATIONAL. The need of an armed service for a specified guided missile system.

REQUIREMENTS, FORCE. The manpower and personnel required by an armed service using a guided missile system for a defined mission.

RESEARCH. A continued process of scientific investigation prior to and during development. It has for its aim the discovery of new scientific facts, techniques, and natural laws.

RESEARCH, APPLIED. Research aimed at specific application of scientific laws, principles, and phenomena. In contrast to basic research, the prospect of practical application of the results is a primary motive for applied research. Frequently even the methods to be used are clear before work is begun.

RESEARCH, BASIC. The theoretical or experimental study directed toward the increase of knowledge. It may result in the discovery of new scientific phenomena, principles, techniques, or significant data which add to the store of scientific knowledge. Immediate practical application is not necessarily a direct objective.

RESEARCH, NONMATERIEL. Research directed toward development or improvement of techniques, rather than toward the development of materiel. It includes such subjects as the application of psychology or of analytical and statistical methods to the study of military problems.

RESEARCH, OPERATIONS. (1) The scientific, qualitative, quantitative study of warfare by military agencies with the objective of improving the weapons, tactics, and strategy of future operations through analysis and evaluation of past operations and maneuvers and operations trials. This activity is also known as Operational Research, Operations Analysis, and Operations Evaluation. (2) A scientific method of providing executives with a quantitative basis for decisions regarding the operations under their control.

RESIDUAL CONTAMINATION. Nuclear radiation remaining after an atomic warhead detonation. Usually refers to radiation from the cloud or from fission products deposited on the ground.

RESILIENCE. The resilience of a body measures the extent to which energy may be stored in it by elastic deformation. The implication of the word "stored" in the above definition is that this energy may be released in the form of mechanical work when the force causing the elastic deformation is removed, and that resilience is a property of a material within its proportional limit. The "modulus of resilience" is the maximum energy storage in a unit volume of the material. In practical units it is the inch pounds of energy stored in a cu. in. of the material stressed to the proportional limit (**elastic limit**). The modulus of resilience is directly proportional to the square of the stress, and inversely proportional to the modulus of elasticity.

RESILIENCE, MODULUS OF. The energy stored in a cubic inch of an elastic material at the bottoming point of that material when under stress.

RESISTANCE. The uses of this term in engineering are in accordance with its general meaning of "that which tends to oppose motion." (1) Mechanical resistance is the opposition offered by a material body to forces which tend to produce motion. This mechanical resistance may arise from friction, from stresses set up in rigid anchors, or from inertia. Whenever the power dissipated in friction is proportional to the square of the velocity, mechanical resistance may be defined as the real part of **mechanical impedance**, the unit of which is the mechanical ohm. (2) Electric conductors are believed to contain free electrons, the movement of which through the substance constitutes **electric conduction**. In this migration the moving particles evidently meet with some restraint, since heat is generated. Electrical resistance is the factor by which the square of the instantaneous conduction current must be multiplied to give the power lost by dissipation as heat or other permanent radiation of energy away from the electric circuit. (Consider the "radiation resistance" of an antenna.) The unit of electrical resistance is the **ohm**. (3) Acoustic resistance is defined as the real component of acoustic impedance, the commonly-used unit being the acoustic ohm. Acoustic flow resistance (d-c acoustic resistance) is defined as the quotient of the

pressure difference between the two surfaces of a sound-absorbing material by the volume current through the material. (4) Fluid resistance is the opposition offered by gases or liquids to the passage of bodies through them.

RESISTANCE, MECHANICAL RECTILINEAL (MECHANICAL RESISTANCE). The real part of the **mechanical rectilinear impedance**. This is the part responsible for the dissipation of energy. The unit is the mechanical ohm.

RESISTANCE, MECHANICAL ROTATIONAL RESISTANCE). The real part of the **mechanical rotational impedance**. This is the part responsible for the dissipation of energy. The unit is the rotational ohm.

RESISTOR. An electrical part which offers resistance to the flow of electric current. Its electrical size is specified in ohms or megohms (one megohm equals 1,000,000 ohms). A resistor also has a power-handling rating in watts, indicating the amount of power which can safely be dissipated as heat by the resistor.

RESNATRON. A high-power, high-efficiency, cavity-resonator tetrode designed to operate in the VHF region. Principle of operation is similar to that of a class C **oscillator**, with careful attention to beam focusing playing a large part in the high efficiencies achieved.

RESOJET ENGINE. Also resojet or resonant jet. A **pulsejet** engine that operates at its resonance frequency. Also called an "acoresonator."

RESOLUTION. A term used in a number of specific cases in science to denote the process of separating closely-related forms or entities or the degree to which they can be discriminated. The term is most frequently used in optics to denote the smallest extension which a magnifying instrument is able to separate or the smallest change in wavelength which a spectrometer can differentiate. In this last sense, it is defined as the ratio of the average wavelength (wave number or frequency) of two spectral lines, which can just be detected as a doublet, to the difference in their wavelengths (wave numbers or frequencies). The term resolution is also applied to such varied processes as the separation of

a racemic mixture into its optically-active components or as the breaking up of a vectorial quantity into components. (See **radar resolution**.)

RESOLVER. In automatic **computers**, a device or circuit to convert data from one system into another. For example, a resolver would be used to convert a wind vector into its cardinal direction components, or a resolver might convert polar coordinates into rectangular.

RESOLVING POWER. (1) The ability of an optical system to resolve, i.e., separate, two entities, such as the ability of a telescope to separate the images of the two stars of a double star, the ability of a microscope to separate the images of two points which are close together, and the ability of a spectroscopy to separate two spectral lines. Most studies of resolving power are based on the **Rayleigh criterion** of resolving power. (1a) The resolving power of a microscope is given by the relation $d = 1.22\lambda/2 \text{ N.A.}$, where d is the linear separation of two points, λ is the wavelength used, and N.A. is the numerical aperture of the object lens. (1b) Most telescopes have large objective lenses in order to have large light-gathering power, and to have high resolution. This high resolution may produce resolved images too close together to be resolved by the human eye. Hence an eye-lens or ocular is included in the system for the purpose of magnifying the initial image so that the eye can see it as resolved. Note that no amount of magnification of the initial image can increase the resolving power of the telescope over the resolving power of the objective lens. (2) By extension, the term applies to instruments separating particles. The resolving power of a mass spectroscopy is the highest value of the ratio $m/\Delta m$ for the complete separation of the mass spectrum lines differing by Δm in mass. (3) In a unidirectional antenna, the resolving power is the reciprocal of its **beam width**, measured in degrees. The resolution of a directional radio system can be different from the resolving power of its antenna, since the resolution is affected by other factors.

RESONANCE. Every physical system, in general, has one or more natural vibration frequencies characteristic of the system itself and determined by constants pertaining to the system. Thus a flexible string of length l and

mass δ per unit length, and subjected to a tension f , will, if struck or plucked and left to itself, vibrate with frequencies equal to

$$\frac{1}{2l} \sqrt{\frac{f}{\delta}}$$

and to various integral multiples thereof (overtones). If such a system is given impulses with some arbitrary frequency, it will necessarily vibrate with that frequency even though it is not one of those natural to it. These "forced vibrations" may be very feeble; but if the impressed frequency is varied, the response becomes rapidly more vigorous whenever any one of the natural frequencies is approached, its amplitude often increasing many fold as exact synchronism is reached. This effect is known as resonance. The many uses of this conception in engineering and science stem from this initial use in mechanics or acoustics to denote a prolongation or reinforcement of sound by induced vibration. There are two types of electrical resonance, series and parallel. In series resonance, equality or near equality between inductance and capacitance in series in an a-c circuit reduces the impedance essentially to the resistance alone, causing maximum current for a given impressed voltage. For a circuit composed of an inductance in parallel with a capacitance, the opposite effects of these two types of reactance will counteract one another at some frequency and produce unity power factor for the circuit. This is parallel resonance, or "antiresonance," as it is sometimes called.

RESONANCE FREQUENCY. (1) For a general discussion of resonance frequency, see forced **oscillations**. (2) A frequency for which some measure of the **response** of a circuit element is maximum (or minimum). Thus amplitude resonance occurs at that frequency for which a given amplitude stimulus yields a maximum amplitude response, phase resonance occurs when the response is in phase with the stimulus (i.e., at the frequency yielding zero reactance), and period resonance occurs when the driving-force frequency is the natural frequency of the circuit element. (3) The frequency of a mode of elastic vibration of a crystal such as quartz, which is coupled through the **piezoelectric effect** to an electrical system.

RESONANT BURNING. In solid-propellant rocket design, the phenomenon of unstable combustion vibration resulting in acoustical **resonance**. (More commonly termed “chugging” or “screaming.”)

RESONANT FREQUENCY. That frequency at which the **magnification factor** is at a maximum. It normally occurs when the natural frequency of the item and the forcing frequency are the same.

RESPONDER. 1. A **transponder**. 2. The receiver unit in a transponder. (See also **beacon**.)

RESPONDER BEACON. The radar beacon that serves to emit the signals of the responder in a **transponder**.

RESPONSE. A quantitative expression of the output of a device or system as a function of the input. The response of a missile may be expressed by an analysis of the **servomechanism** loops involved, leading to separate response equations for the individual loops or a single equation, usually in differential form, for the missile.

RESPONSER. That component of an **interrogator-responder** that receives and displays the reply from the responder beacon.

RESTING FREQUENCY. The frequency to which the carrier of a frequency-modulated transmitter returns during non-modulating intervals.

RESTING MOMENT. The moment of a hypothetical single force acting on the center of gravity of a body, equal and opposite to the resultant of **lift** and **drag** acting through the center of pressure. It exerts a moment which keeps the body stable, or which must be applied to insure stability. For a stable rocket, the center of pressure is to the rear of the center of gravity, thus providing a positive restoring moment.

RESTRICTED AREA. A security or classified area to which access is controlled.

RESTRICTED BURNING GRAIN. A solid-propellant rocket grain in which the burning surface is restricted or inhibited to provide particular pressure-time characteristics.

RESTRICTED DATA. A security classification for all data concerning the manufacture or utilization of atomic weapons, the production of fissionable material, or the use of fissionable material in the production of power, but not including any data which the Atomic Energy Commission from time to time determines may be published without adversely affecting the common defense and security.

RESTRICTED PROPELLANT. Propellant, restricted.

RESULTANT. An entity or quantity obtained by means of (or as the result of) a given process. Thus, the resultant of a system of forces is the single force that has the same effect.

RETENTIVITY (B_r). That property of a magnetic material which is measured by the residual induction (see **induction**, **residual**) when a saturating **magnetizing force** is removed. (See **hysteresis**.)

RETICLE. A network of fine lines, wires, or the like placed in the **focus** of the **objective** of a telescope or other optical instrument.

RETMA. Radio, Electronics, and Television Manufacturers Association.

RETRACTABLE LAUNCHER. Launcher, retractable.

RETROFIT (BACKFIT). A modification of a missile or other equipment to incorporate changes made in later production of a similar piece of equipment. Retrofitting may be done in the factory or field.

RETROGRADE ORBIT. A satellite orbit in which the inclination angle is greater than 90° , causing it to proceed westward, i.e., in a sense opposite to the rotation of the Earth. An orbit directed in the same direction as the rotation of the Earth, i.e., eastward, is called a direct orbit.

RETRO-LAUNCHING. Launching a missile backward relative to its parent airplane in order to reduce its air speed to near-zero.

RETRO-ROCKETS. Rocket units, usually of solid-propellant type, used to retard one body relative to another: e.g., fired opposite to main power units to separate burned out stages.

RETURN TIME. Radar range measurement.

REVERBERATION. The persistence of sound at a given point, after direct reception from the source has stopped. This may be due (a) (as in the case of rooms) to repeated reflections from a small number of boundaries or to the free decay of the normal modes of vibration that were excited by the sound source; (b) (as in the case of underwater sound in the ocean) to scattering from a large number of inhomogeneities in the medium or reflection from bounding surfaces.

REVERSIBLE PROCESS. In thermodynamics, a process that involves a change which can be reversed in direction by an infinitesimal change in conditions.

REVERSING LAYER. The lower part of the sun's atmosphere is frequently referred to as the reversing layer. It is a gaseous layer which is cooler than the **photosphere**, only a few hundred miles in thickness, and gradually merges into the **chromosphere**. The reversing layer receives its name because it is in this region of the sun that the thousands of dark lines in the solar spectrum, commonly known as the Fraunhofer lines, are produced. As a result of a tremendous amount of research on the identification of the Fraunhofer lines, it is confidently believed that they are all due to elements which are to be found on the earth. These elements are reduced to the gaseous state in the reversing layer because of the tremendous heat from the photosphere.

REYNOLDS NUMBER. In aerodynamics, a non-dimensional coefficient used as a measure of the dynamic flow. Its usual mathematical form is:

$$Re = \frac{\rho VL}{\mu}$$

where Re is the Reynolds Number, ρ is the density of the fluid, V is the velocity of fluid flow, L is the linear dimension of the body in the flow, and μ is the coefficient of viscosity of the fluid.

RF. Frequency, radio.

RFA. Requests for alterations, e.g., in a missile design.

RGZ. Recommended ground zero.

Rh. Rhodium.

RHEINBOTE. A German World War II multi-stage, surface-to-surface rocket consisting of three stages, plus a **booster** for takoff.

RHEINTOCHTER R-1. A German World War II surface-to-air missile propelled by a solid propellant (diglycol dinitrate) sustainer motor. The missile was boosted at takeoff with a solid propellant rocket of 143,000 pounds thrust for a duration of 0.6 seconds.

RHENIUM. Metallic element. Symbol Re. Atomic number 75.

RHEOSTAT. A variable resistor.

RHODIUM. Metallic element. Symbol Rh. Atomic number 45.

RHUMB LINE. (1) A line of constant direction that crosses successive meridians at the same oblique angle, appearing as a straight line on a **Mercator projection**. (2) Any line of constant direction, including meridians, parallels, and the equator.

RHUMBATRON. A resonant cavity (used instead of circuits) consisting of lumped inductance and capacitance, to act as an **oscillator** capable of giving several kilowatts output at frequencies of several thousands of megacycles.

RHUMB LINE DISTANCE. Distance measured along a **rhumb line**, i.e., a line on the surface of the earth making the same angle with all meridians.

RI. Radio Inertial (guidance system).

RIBBON PARACHUTE. A parachute consisting of strips of material joined to form a porous canopy, especially suited to opening at high speeds. It is usually designed so that spreading of the ribbons at high velocity of fall permits air to pass through and prevents excessive deceleration.

RIGEL. (1) A U.S. Navy ramjet surface-to-surface missile developed by the Grumman Aircraft Co. The missile project was dropped to an inactive status in early 1954. (2) A star of the constellation **Orion**.

RIGHT ASCENSION. The arc of the celestial equator, or the angle at the celestial pole, measured eastward from the **hour circle**

of the vernal equinox to the hour circle of a given celestial body, either through 24 hours or 360 degrees.

RIGIDITY OF THE TRAJECTORY. In ballistics, the assumption that any projectile trajectory may be moved in azimuth or altitude (i.e., "up" or "down") with no change to the shape characteristics of the trajectory.

RIME. A variety of ice forming on terrestrial objects or air vehicles by condensation of air moisture. It is rough in texture and white-opaque in color.

RING MODULATOR. A rectifier modulator (demodulator) employing four diode elements connected in series to form a ring. The diodes are arranged in a polarity sequence which readily permits current flow around the ring in one direction. Appropriate input and output connections are made to the four nodal points of the ring. The ring modulator is also termed the double-balanced modulator. It can serve as a balanced modulator, as well as a phase-sensitive detector or demodulator.

RINGING. An oscillatory transient occurring in the output of a system, as a result of a sudden change in input.

RINGING OSCILLATOR. An oscillating circuit which accepts a negative square pulse at its input and gives at its output, a series of high frequency oscillations of a fixed duration in time. The output frequency of a ringing oscillator is determined by the value of the inductance and capacitance in the tank circuit. The ringing oscillator is often used to produce range markers on radar range scopes.

RINGTIME. The time interval between the beginning of a radar pulse and the instant at which the energy reradiated from an echo box falls below the minimum required to produce an indication in a radar receiver. (See recovery time.)

RIPPLE. The alternating-current component present in the output of a direct-current generator, rectifier system or power supply.

RIPPLE FIRE. The launching of guided missiles in close succession.

RIPPLE VOLTAGE. The alternating component of the unidirectional voltage from a

rectifier or generator used as a source of direct-current power.

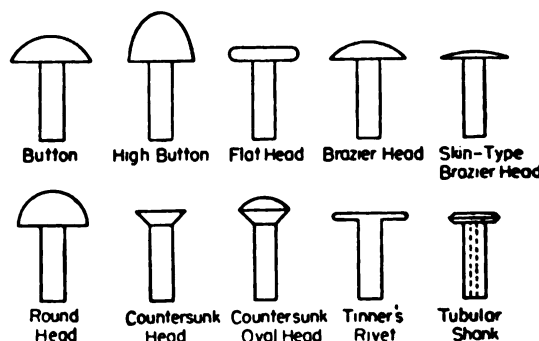
RISE (RESEARCH IN SUPERSONIC ENVIRONMENT). A U.S. Air Force program carried out by North American Aviation using vehicles remaining from the Navaho program, which was discontinued in 1957. The first RISE launchings were made at Cape Canaveral, Florida in the summer of 1958. The objectives of the RISE program were to investigate high speed flight conditions preliminary to manned space flight attempts.

RISE TIME. The time required for an electrical quantity to rise to some arbitrary fraction of its maximum amplitude. (90% in the case of a radar pulse.)

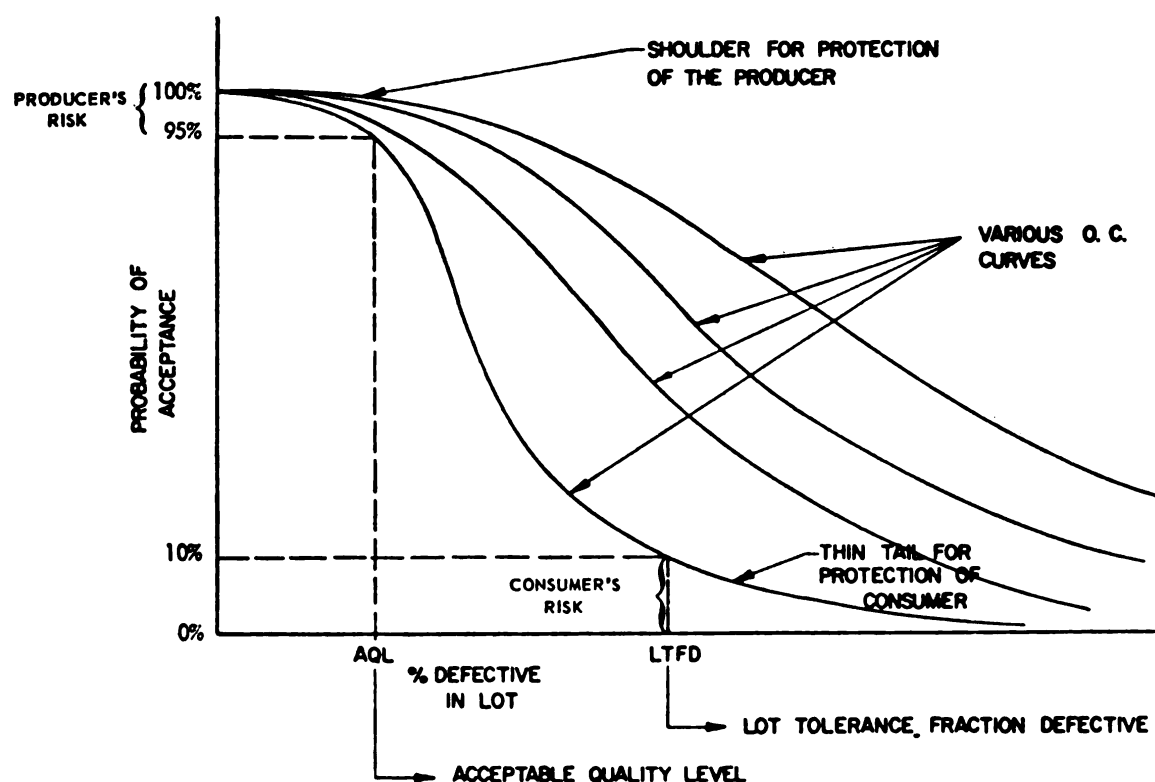
RISK. The probability of making an incorrect decision.

RISK (PRODUCERS AND CONSUMERS). A concept used in reliability and test activities to avoid having either the consumer or the producer accept most of the risk for the acceptability of the product. The concept is based on the probability that the consumer will accept a defective product a definite number of times and that he will reject a good product an equal number of times, or at any rate, another definite number of times; also that the producer will deliver with a certain probability a defective product or that he will reject a good product. (See Fig. on Page 525.)

RIVET. A cylindrical fastening, with one preformed head, inserted in two or more plates, holding them together by the pressure exerted between the preformed head and the fabricated head at the other end. The pressure can be produced by forging the heated rivet in place or by explosion of a small charge con-



Forms of rivets.



Typical operating characteristic curves of sampling plans.

tained in the projecting shank of the rivet. Rivets are of many designs, as shown by the representative forms in the figure.

Rn. Radon.

ROBIN. A U.S. World War II guided bomb using a radio-command link with television camera presentation.

ROBO. Rocket orbital bomber.

ROBOT BOMB. A self-propelled, winged bomb that automatically keeps on course and descends on its target. Applied particularly to the German V-1 winged jet bomb of WW II or a bomb of that type.

ROBOT PILOT. Automatic Pilot.

ROC. A U.S. World War II guided bomb. Two types of guidance were planned for this missile: a radio command using telescope tracking, and a television-radio command. The missile was basically a 1000 pound bomb, equipped with an annular airfoil surface amidships. Within this annular surface were four stubby wings. The missile never saw actual operational use, but was approaching the pro-

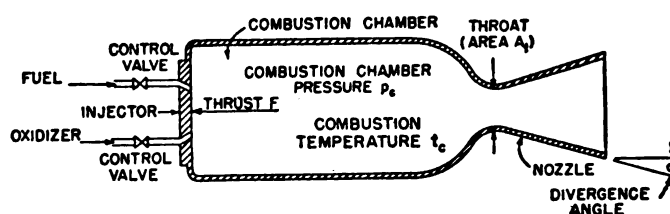
duction stage at the end of the war. Steering was accomplished by moving a tail-end shroud (similar to the annular airfoil surface amidships). The missile was also called the ROC-OO and the "Double Cookie Cutter" because of the two "O"-shaped shrouds.

ROCHE LIMIT. In celestial mechanics, the minimum and limiting distance of approach of a satellite to its primary beyond which the attraction of the primary will cause a break-up of the secondary. It is 2.44 radii of the primary from its center. The Roche limit applies only to celestial bodies held together by their own gravitation and does not apply to small artificial satellites whose structural integrity is obtained from forces other than their own gravitational field. The rings of Saturn are 2.3 radii out and are therefore within the Roche limit and are believed to have resulted from break-up of one or more large bodies.

ROCK-AIR. An airborne launching system developed in 1956 by Douglas Aircraft Company, in which an aircraft carries the missile to a high altitude, turns into a steep climb attitude at the moment of launch, and fires the missile. The system was proposed as an

inexpensive method for launching atmospheric-sounding rockets. The system called for the launching aircraft to attain a speed of Mach 0.8 at 35,000 feet, where an Aero-sound rocket, either in a single-stage or a multistage form, would attain an altitude of 45 miles with a 40-pound payload. A system using two stages could theoretically reach 110 miles with a 40-pound payload.

ROCKET. (1) A missile or pyrotechnic device propelled by hot gases ejected rearward by a motor; also an air vehicle that utilizes this kind of propulsive force. (2) An engine or motor that moves forward by ejecting a stream of hot gases to the rear, and which, carrying its own oxidizer, is independent of the atmosphere in its operation. (See figure.)



Principal elements of a rocket motor.

(3) Any one of the combustion chambers or tubes of a multichambered rocket engine. (See **rocket engine**; **rocket motor**, **rocket propulsion** and **jet engine**.)

ROCKET ADAPTER. An adapter for launching rockets of different sizes from the same vehicle. (See **launcher adapter**.)

ROCKET AIRPLANE. (1) An airplane using rocket propulsion for its chief or only propulsive power. (2) An airplane fitted out to carry and fire rocket ammunition.

ROCKET ARTILLERY. Artillery rockets are usually of the solid-propellant type with unrestricted burning charges which deliver their thrust over a period of a few seconds. High initial accelerations are desired to prevent accuracy loss by wind effects. In view of the high expense of guided rockets, these are only used for high energy warheads. For saturation coverage of areas, unguided or pre-set rockets are normally used as artillery.

ROCKET ASSISTED TAKEOFF. RATO.

ROCKET BOMB. (1) An aerial bomb equipped with a rocket to give it added ve-

locity and penetrating power after being dropped from an aircraft. (2) A **guided missile**, **ballistic missile**, or similar device, using rocket propulsion.

ROCKET, BOOSTER. Booster rocket.

ROCKET, DUCTED SOLID PROPELLANT. A type of missile propulsion system which uses a solid reductant (fuel) contained in a duct with air serving as the oxidant. This type of rocket is known as a solid propellant ramjet and is not a pure rocket system; i.e., it is an air-breathing engine.

ROCKET ENGINE (ROCKET MOTOR).

(1) A type of propulsive device which develops thrust independently of the medium in which it operates. The classes are:

- Liquid propellant rocket engine* (all of the propellants being in the liquid state prior to their injection into the rocket motor).
- Solid propellant rocket engine* (the chemicals being in the solid state before chemical reaction is initiated).
- Nuclear rocket engine* (a nuclear reactor being used to accelerate a self-contained fluid).
- Photon rocket engine* (a source of light photons being used to develop thrust).

(See Fig. 1.)

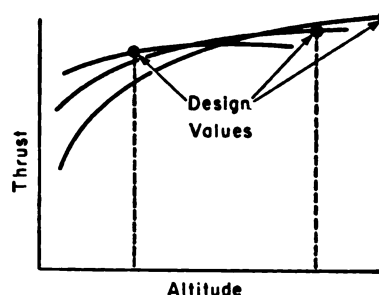


Fig. 1. Rocket engine thrust. (Engine designed for higher altitude develops more thrust at design altitude than any other.)

(2) A propulsive component of a guided missile. In rocket usage that part of the propulsive system actually produces the thrust. It includes auxiliary pumps and drives and is a self-contained unit but does not include the tankage, pressurization or control systems. (See Fig. 2.)

The flow process in the motor is regarded as adiabatic and isentropic. This is not strictly correct, even if no heat loss occurs through the wall and no friction and turbulence exists, because the gas is partly dissociated. Its heat content, therefore, exists of a "sensible" portion, expressed by its instantaneous tempera-

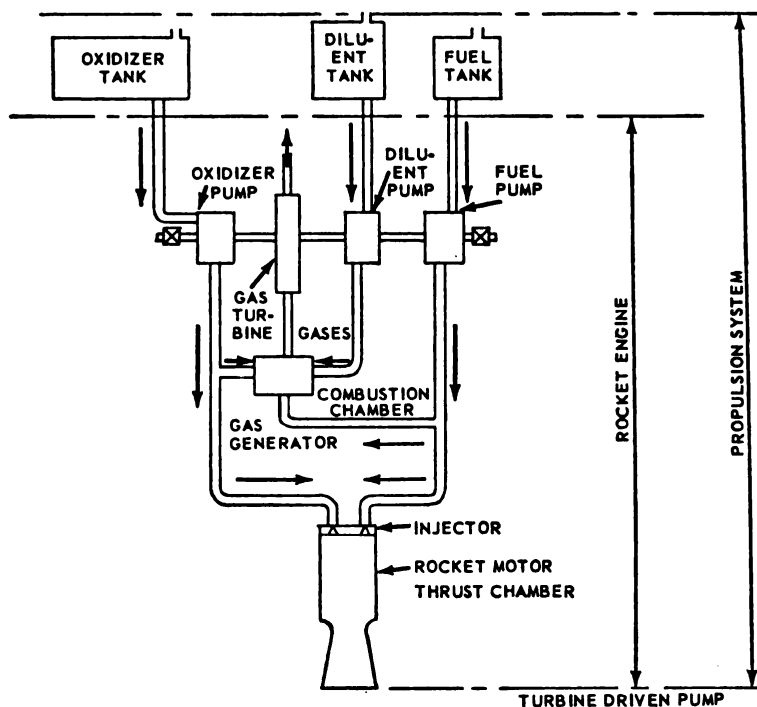


Fig. 2. Bipropellant rocket jet propulsion system employing a turbine driven pump for pressurizing the propellants.

(3) There is noted a tendency to employ the term "rocket engine" in reference to the relatively complicated liquid-propellant types and to use "rocket motor" as a general term embracing both liquid-propellant and solid-propellant types; no sharp distinction between the terms has been observed, however.

ROCKET ENGINE, IDEAL. In the ideal rocket engine, hot and completely burned gas is at rest in the combustion chamber at a pressure p_c . It attains sonic speed in the throat and thereafter expands completely into the ambient supersonic flow regime. Effects of turbulence, incomplete combustion, friction, and heat losses are not considered. Likewise, no assumptions are made concerning the geometrical configuration of the motor except that it must have a divergent exhaust nozzle which begins at a point where the gas has attained **critical velocity**.

ture and by a "chemical" portion, expressed by its instantaneous molecular and atomic composition. The sensible part represents the internal energy of the gas. The chemical part consists of the energy of dissociation temporarily absorbed by the dissociated molecules and released upon their recombination. This recombination is equivalent to an exothermic chemical reaction, i.e., a reaction which releases heat, like a combustion. Therefore, by recombination, chemical heat is converted back to sensible heat.

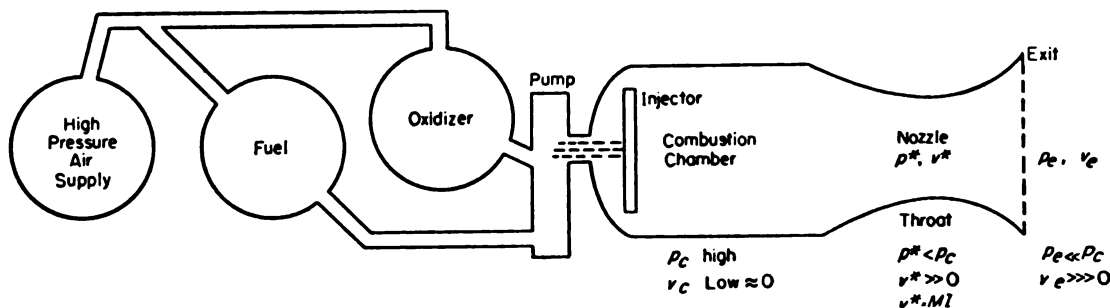
When expanding, the gas converts sensible heat to kinetic energy. The process is truly adiabatic only, if the total amount of sensible heat (not the sum of sensible *and* chemical heat) is constant. Recombination of dissociated molecules during expansion changes the total amount of sensible heat, thus causing deviations from correct adiabatic flow processes. Moreover, entropy losses are

caused by the exothermic reaction in a fast moving gas.

ROCKET ENGINE, LIQUID PROPELLANT. A rocket engine in which all of the propellants are in a liquid state prior to their injection into the combustion chamber.

ROCKET ENGINE NOMENCLATURE. A standardized form for the identification of

ROCKET ENGINE PARTS. A rocket engine consists of three main parts: an exhaust nozzle to convert heat energy into kinetic energy by adiabatic expansion, a combustion chamber where propellants react in an exothermic process, and an injector which introduces the propellants into the combustion chamber in the proper burning mixture. A stylized rocket engine is shown in the figure.



Rocket engine, schematic.

rocket engines has been devised. It consists of three elements: time of burning, type of propellant, and thrust. As an example: 21 AL 2600, is a 21 second acid-liquid engine of 2600 pounds thrust. In this system, the following letter designations for propellant types are used:

- A—Acid; or asphalt and perchlorate
- AS—Asphalt and perchlorate solid
- B—Ball or chopped
- C—Composite
- D—Cast double base
- E—Extruded double base
- F—Furfuryl alcohol
- K—Perchlorate fuel (not asphalt)
- N—Nitrate and nitro compounds
- O—LOX-alcohol or hydrocarbon
- L—Liquid
- S—Solid
- P—Plastic

Rocket Engine Performance Parameters. The following parameters are commonly used to describe rocket motor performance:

- F—Thrust
- F_v —Velocity thrust
- F_p —Pressure thrust
- C_F —Coefficient of thrust
- c —Effective exhaust velocity
- c^* —Characteristic velocity
- SPC—Specific propellant consumption
- I_{sp} —Specific impulse
- V_e —Exit velocity

ROCKET ENGINE PRINCIPLE. Rocket engines are operated upon **Newton's third law of motion**. Propellants are burned in a combustion chamber and allowed to expand through an exhaust nozzle which first converges and then diverges. If the pressure is great enough, the gas flow is accelerated to sonic velocity at the nozzle throat. The pressure at the combustion chamber end results in the production of an unbalanced force which propels the motor in the opposite direction from the gaseous flow. The thrust developed by an engine is given by the relationship:

$$F = \frac{v}{g} \frac{dW}{dt} + A_e (P_e - P)$$

where $\frac{dW}{dt}$ is the propellant flow rate, v is the nozzle exhaust velocity, A_e is the nozzle exit area, P_e is the exit pressure, and P is the atmospheric pressure.

Thrust is also given by:

$$F = c \frac{dm}{dt} = V_e \frac{dm}{dt} + (P_e - P) A_e$$

where $\frac{dm}{dt}$ is the mass flow rate, c is the effective exhaust velocity, v_e is the exhaust velocity, P_e is the exit pressure, P is the atmospheric pressure, A_e is the exhaust area. (For further information see **effective exhaust velocity and thrust**.)

ROCKET ENGINE, REAL. The principal effects which cause a deviation of actual rocket engine performance data from their ideal values are nozzle divergence, friction, incomplete combustion, and wrong exit or chamber pressures.

Due to divergence of the exhaust nozzle, the gas particles are not accelerated parallel to the engine axis, but at certain angles to it. Therefore, the acceleration can be subdivided into two components, parallel and normal to the engine axis. Of these components only the acceleration parallel to the engine axis produces useful thrust. Acceleration normal to the axis consumes propellant energy without contributing to the thrust.

Friction on the walls retards the gas and reduces the weight flow. If the friction force, which acts opposite to the thrust force, is subtracted from the thrust force, the resulting thrust is equivalent to the theoretical thrust at lower exhaust velocity.

Incomplete combustion is one of the dominant causes for deviation from ideal performance. It reduces the exhaust velocity since not all energy is liberated by chemical reaction, as normally is assumed when computing the theoretical exhaust velocity. Incomplete combustion further reduces the chamber temperature, hence increases the mean density of the gas so that more matter can pass through the throat. Thus the weight flow is increased above the theoretical value. Delayed reaction of unburned material in the nozzle (afterburning) disturbs the flow and causes deviation from isentropic conditions.

Wrong pressure refers either to the nozzle exit pressure or to the chamber pressure. The nozzle exit pressure is correct if it is equal or close to the ambient pressure of the atmosphere surrounding the motor. If the exit pressure is smaller or larger, a negative or positive pressure thrust is produced. Unless the nozzle is capable of changing its geometric shape (variable-geometry nozzle) it can be laid out only for one given ambient pressure. The rapid decrease in atmospheric pressure during powered ascent of the rocket soon causes the ambient pressure to drop below the nozzle exit pressure, producing a pressure thrust which increases as the vehicle gains altitude. This pressure thrust augments the momentum thrust. However, if the expansion ratio of the nozzle could be increased so as always to give zero pressure difference at

the exit, the gain in momentum thrust would be greater than the augmentation by pressure thrust (at least down to 0.1 atm ambient pressure).

Aside from the altitude effect which causes the nozzle exit pressure to deviate from the correct ambient value, the nozzle exit pressure can become incorrect due to wrong chamber pressure. The chamber pressure is wrong if it deviates from the value for which the injection system and injection pressure are designed. Incomplete combustion reduces the chamber pressure and consequently also the nozzle exit pressure. The exit pressure becomes too low at incomplete combustion, causing a negative pressure thrust which reduces the overall performance. This effect has to be taken into account when dimensioning the nozzle. The reduction in chamber pressure influences the operation of the injection system. However, this effect is appreciable only at large chamber pressure reductions below the value for which the injection system was laid out.

ROCKET ENGINE, SOLID PROPELLANT. Solid propellant rocket engine.

ROCKET FUEL. A fuel, either in liquid or solid form, developed for, or used by, a rocket.

ROCKET, HYBRID. A solid-propellant rocket, employing either an auxiliary liquid propellant or some other working fluid, e.g., air.

ROCKET IGNITER. An igniter for igniting the propellant in a rocket.

ROCKET LAUNCHER. A device for launching rockets.

ROCKET MISSILE. A missile using rocket propulsion.

ROCKET MOTOR GAS FLOW. In a rocket motor, as in an air-breathing jet engine, chemical reaction and gas flow are the two basic phenomena. However, they are fairly well, though not completely, separated. The main reason for this separation is that in a rocket motor the air is replaced by some other oxidizer, either pure oxygen, or an oxygen carrier, stored in containers and injected into the combustion chamber at comparatively very low speed. Thus no foreign medium is

rushing into the motor at high speed. The directed gas flow commences in the chamber. Most of the reaction takes place in this phase, where there is very little gas flow. Later, when the gas moves at high speed, the rate of reaction is small. The gas moves from a state of nearly complete rest through a duct of gradually decreasing diameter (convergent nozzle) to a point where the duct area is a minimum (throat). During this process the gas is accelerated steadily, converting pressure and temperature to kinetic energy. It attains sonic velocity in the throat. Thereafter, further acceleration can be accomplished only by enlarging the duct again (divergent nozzle), since at a pressure which is lower than the one at which sonic speed is attained, the specific volume of the gas increases more rapidly than its velocity can possibly increase. The enlargement of the duct is necessary, in order to accommodate the greater volume.

In the fast moving gas around and behind the throat, pressure changes cause changes in gas density which cannot be neglected. These so-called "compressibility effects" are taken into account in the laws of gas dynamics.

If the Mach number is very small, that is, the gas velocity is only a small fraction of the local velocity of sound, changes in static pressure of the flow do not produce any appreciable changes in the local gas density. In this flow region the simpler laws of hydrodynamics, the dynamics of incompressible fluids, apply. In normal air the maximum density which can occur at $M = 0.32$ (i.e., gas velocity being 32 per cent of the local sound velocity) is about 5 per cent. If gas, moving at a Mach number of 0.46, is brought to rest at a stagnation point, an increase in density of about 10 per cent is produced. Velocities corresponding to these Mach numbers represent about the upper limit at which the gas flow can still be treated according to the laws of hydrodynamics. In a very rigid sense, the laws of hydrodynamics apply only if the Mach number approaches zero. This terminology is often used in literature to indicate that density variations in the gas flow are negligible or zero.

The motion of a fluid particle can be expressed by three velocity components, parallel to the three axes in space. The so-called axial component runs parallel to the nozzle axis and normally is by far the largest one. The two other components are directed normal

to the axis. The gas motion is three-dimensional. If the change in the slope of the nozzle diameter or duct diameter along the axis is sufficiently small, the two normal components are decreased correspondingly. If they are very small as compared to the axial component, they may be neglected entirely and the flow can be treated as though it were one-dimensional. In this case the variation of all properties of the gas passing through the duct or nozzle can be neglected in any direction normal to the axis of the flow. This type of flow, of course requires considerably less computational effort than two- or three-dimensional flow.

Obviously, in a round nozzle the flow can be either three-dimensional or one-dimensional in the first approximation. Two-dimensional flow is an approximation which can be applied only to rectangular nozzles and there the approximation is the more correct the greater the ratio of nozzle width to nozzle height. In view of the very high temperatures and the related material and cooling problems, only three-dimensional nozzles are presently used in rockets. However, annular nozzles and rectangular nozzles can be, and have been, applied for jet engines and for cold gas flow, as it occurs in conventional wind tunnel nozzles, for instance.

In practically all rocket nozzles, the cross-sectional area varies rather gradually, thus the angle of divergence is comparatively small, no discontinuities occur and the nozzle has a conical shape so that non-axial velocity components can be neglected with sufficient accuracy for practical purposes as far as gas dynamic relations are concerned. It may be emphasized, however, that for thrust performance calculations the effect of nozzle divergence must be taken into account.

ROCKET, MULTISTAGE. A rocket or rocket missile having two or more thrust-producing units each used for different stages of the rocket's flight. (Normally, each unit of a multi-stage rocket is jettisoned when fuel is consumed.)

ROCKET-POWERED. Powered by one or more rocket engines or rocket motors.

ROCKET PROJECTILE. A projectile, especially a missile, using rocket propulsion.

ROCKET PROJECTOR. A rocket launcher.

ROCKET PROPELLANTS. Propellants.

ROCKET-PROPELLED. Propelled by one or more rocket engines or rocket motors. (See **jet-propelled**.)

ROCKET PROPULSION. The means whereby thrust is developed by a rocket engine; i.e., the fundamental principle upon which all propulsion prime movers operate is based on Newton's third law; *for every action there is an equal and opposite reaction*.

Upon combustion of the propellants in the burning chamber, the gases expand through the nozzle at a high velocity, the internal pressure at the nozzle end is relieved, causing an unbalanced pressure at the other end which tends to move the chamber and vehicle to which it is mounted in the direction opposite to the issuing jet. Propulsion is dependent upon internal conditions alone and not the effect of the jet "pushing" against the surrounding air.

ROCKET PROPULSION EFFICIENCY.

Since **rocket propulsion** consists of three stages, one can distinguish between three fundamental efficiencies, pertaining to the conversion of original energy into mechanical energy of the working fluid (internal efficiency), conversion of mechanical energy into useful work done on the vehicle (propulsion efficiency) and the product of these two efficiencies (overall efficiency). These efficiencies can be defined as follows:

Internal efficiency, the ratio of mechanical energy produced in the engine to the energy released. In the case of combustion engines, this efficiency is also called "thermal efficiency."

Propulsion efficiency, useful work done on the vehicle divided by the mechanical energy produced in the engine.

Overall efficiency, the product of internal and propulsive efficiency, hence, defined as the useful work done on the vehicle divided by the energy released, or the heat released by fuel and oxidizer.

ROCKET PROPULSION SYSTEM. The purpose of a propulsion system is energy conversion, from a stored form in the vehicle, to kinetic and potential energy of the payload and associated structure. The energy is used to produce **thrust**, which in turn accelerates

the vehicle—the thrust being the reactive force which, in **rocket propulsion**, is exerted by the mass of working fluid leaving the vehicle. The three principal components of any rocket propulsion system are therefore: (1) Energy source, (2) thrust production mechanism, and (3) energy transfer mechanism from source to working fluid.

(1) Upon the basis of the energy source used, propulsion systems can be classified into chemical, solar and nuclear systems.

(2) Upon the basis of the thrust production mechanism, propulsion systems can be classified as follows:

Thermodynamic systems, consisting of acceleration of a gas by expansion (in an exhaust nozzle).

Magnetohydrodynamic systems, consisting of acceleration of an electrically-conducting gas (plasma) by combined thermodynamic-magnetic, thermodynamic-electric or thermodynamic-electromagnetic means.

Electric systems, consisting of the acceleration of ions or charged particles (of solids or liquids) in electric fields.

Fission systems, consisting of the emission of particles from atomic nuclei undergoing **nuclear fission**.

Photon systems, consisting of the emission of quanta of light or other radiation.

(3) Upon the basis of the energy transfer mechanism, rocket propulsion systems can be classified in a considerable number of ways. Chemical energy can be transferred to a gas by **combustion**, by **free radical** (molecular fragment) recombination, or by exothermic decomposition (controlled explosion). Other means that can be used in thermodynamic (thermal) systems include direct solar heating, direct nuclear heating or electric-arc heating. Solar energy can be used in thermodynamics thrust-production systems (direct heating), as well as in electric systems (arc-heating). The magnetohydrodynamic system may operate on the basis of a more or less weakly ionized arc-produced plasma (arc-magnetohydrodynamic system) or on the basis of a very highly conducting (almost completely ionized) nuclear plasma produced directly by a controlled nuclear reaction (**fusion system**). The electric system may accelerate charged atoms or molecules (ion or ionic system) or very small ionized dust particles or droplets (charged particle system). The only sufficiently powerful source

of photons is the fusion process. Thus, a fusion system almost inevitably will produce at least part of its thrust by photon emission (partial photon system). If one would succeed in converting all matter involved in the fusion reaction to radiation, one would have the total photon system.

At this point the family of propulsion systems has grown to confusing proportions. However, certain simplifications can be made for practical purposes.

First, some propulsion systems are either still in the visionary stage or they show little promise in their present conception. To the visionary group belong the fusion-photon systems. They can therefore be combined as mentioned above and will be discussed only briefly below.

The fusion system operates on the basis of interaction among atomic nuclei, while the chemical system operates on the basis of interactions among the electrons surrounding the nuclei. In nuclear fusion, therefore, the energy release is of the order of 10^6 to 10^7 times greater than that obtainable from chemical reactions. A large portion of this energy is released in the form of intense radiation in the ultraviolet, X-ray and γ -ray region. At least some thrust can be expected from the radiation, but this advantage is by far outweighed, at the present state of technology, by the enormous shielding problems to protect living beings and organic matter used in the system from destruction within a considerable distance of the fusion system. At the present time no material is available which, upon controlled decomposition, releases sufficient energy to be competitive with the combustion or the free-radical system. Chemicals of this sort, such as hydrogen-peroxide (H_2O_2), are used for auxiliary purposes only and for the same purpose (e.g., in gas generators, and as control jets) one could use hydrazine (N_2H_4), tetranitromethane ($C(NO_2)_4$) or ozone (O_3) if this is found desirable. It is conceivable, however, that the picture may change in the future.

Secondly, certain possible correlations between energy source and transfer mechanism do not appear as promising as others. For example, an arc-heated system or an ion system could be energized by solar radiation or by nuclear energy. Closer inspection of the facts involved shows, however, that the use of a nuclear reactor would be so much more ad-

vantageous that one can practically rule out solar-energized systems of this type. This too is not final, of course. An important reason is the low efficiency of arc-heated or electric systems, due to a large number of intermediate conversion steps. Progress in the field of direct power conversion or large improvements in conversion efficiencies could change the picture. In general, it must be kept in mind that the situation in the field of advanced propulsion systems research and development is quite fluid at the present time. All statements and opinions should therefore be understood as of today.

ROCKET PROPULSION SYSTEM TYPES.

In the energy spectrum of astronautic missions, there is a minimum amount of energy required per unit vehicle weight completing the mission. Two groups of missions are recognized. The first group pertains to vehicles fired from the Earth's surface on a one-way mission; the second group is to make a round-trip along co-tangential transfer orbits from, and back to, an Earth satellite orbit. For comparison, consider the energy levels of the V-2 and the ICBM. The V-2 engine had a **specific impulse** of 200 sec. It is seen that the kinetic energy per unit weight of exhaust gas was greater than the kinetic energy per unit weight of the missile at cut-off. There can be no such favorable condition for a chemical ICBM, and much less for astronautic missions with chemical vehicles. This fact leads to much higher mass-ratio requirements, to multi-stage vehicles and eventually to staged operations, such as the use of orbits in terrestrial space for launching interplanetary expeditions.

A more favorable relation between energy demand and supply can be restored in the range of a 600 to 1,200 sec specific impulse. For practically all missions in the solar system, the electric system establishes the same or an even better relation between mission energy and propulsion energy, as it existed for the V-2.

However, for this system only very low accelerations appear feasible, resulting in long flight times. Especially for operations in cis-lunar space, transfer times between Earth and Moon become significantly longer under these conditions (weeks instead of days), but also interplanetary transfer times, at least in the inner solar system, tend to become longer

than those connected with minimum energy transfer ellipses. It is, therefore, of interest to investigate propulsion systems between the chemical and the electric drive, yielding potentially higher accelerations.

Indeed, an appraisal of advanced propulsion systems from the mission standpoint, is governed primarily by three parameters.

An optimization of the propulsion system involving the establishment of the most attractive compromise between three main characteristics, rather than a maximization of the specific impulse per se.

The establishment of initiated satellites must rely on propulsion systems capable of taking off from the Earth. Subsequent operations in cislunar space can be conducted on a very low acceleration level. However, there is a limit to what one is willing to accept in this case, for two reasons: Firstly, impulse drives are not as urgent as for interplanetary operations. Secondly, because the energy level is not too high, very short flight times of 2 days or less between Earth and Moon are desirable. Such operations require high specific impulse (but not extremely high) and an initial thrust-to-weight ratio of at least 10^{-2} g. Specific impulses around 1,000 sec. are quite satisfactory for fast cislunar missions, so that much higher specific impulses, accompanied by very low thrust-to-weight ratios, would not be attractive, since the logistics advantage is overshadowed by the disadvantage of long flight times (mission periods). The table provides a survey over the correlation between initial acceleration and flight time to the Moon. It is seen that for initial accelerations of 10^{-3} g and less the transfer period becomes appreciably greater.

For lunar landings and take-offs, thrust-to-weight ratios of at least 0.2 g are required using Earth g's as measuring units.

For operations in the inner solar system, however, conditions change. Because transfer times of hundreds of days are involved here, even propulsion periods such as found for 10^{-4} g, namely, about 40 days, are quite acceptable. It is found that even for very fast round-trip missions, transfer periods of 90 to 200 days are involved and overall mission periods of the order of one year. On the other hand, as the initial acceleration drops to about 10^{-5} g, powered flight is required all the way to the nearer planets. The ensuing flight times, as Stuhlinger has shown, are about 450

days, i.e., much longer than even the longest transfer time with chemical vehicles.

Finally, for flights into the outer solar system, one has—even for heliocentric parabolic transfer orbits—transfer periods of 1.2 years to Jupiter and 2.7 years to Saturn, hence, total mission periods which are long enough to even accommodate as low initial accelerations as 10^{-5} g.

One can therefore classify the propulsion systems, according to the effect of initial acceleration capability on astronautic missions, as follows:

- Class I *Take-off and Landing Systems:*
 $n_0 \geq 2 \cdot 10^{-1}$ g
Chemical and nuclear-heated systems
- Class II *Fast Cislunar Systems:* $n_0 \geq 10^{-2}$ g
Nuclear heated systems
- Class III *Fast Systems for Inner Solar System Missions:* $n_0 \geq 10^{-4}$ g
Nuclear heated systems
Solar heated systems
Arc-thermo systems (conditionally)
Electric systems (conditionally)
- Class IV *Fast Systems for Outer Solar System Missions:* $n_0 \geq 10^{-5}$ g
Arc-magneto-hydrodynamic systems
Ionic systems
Fusion-photon systems (conditionally)

The systems listed above may be defined as follows:

A chemical system utilizes the energy of an ordinary chemical reaction—i.e., a reaction between molecules and/or stable atoms.

A nuclear system or nuclear-heated system utilizes the energy of a **nuclear reaction**.

A solar system or solar-heated system utilizes the radiant energy of the sun.

An arc-thermo system utilizes the heat of the electric arc.

An electric system utilizes the acceleration of charged atoms, molecules or particles in electric fields. If the particles are atoms or molecules, the system is an ion system or ionic system; if they are solid particles or droplets, the system is a charged particle system.

Magnetohydrodynamic systems may operate on the basis of a more or less weakly ionized

arc-produced plasma (the arc-magnetohydrodynamic system), or on the basis of a very highly conducting nuclear plasma produced directly by controlled nuclear reactions (fusion system). If the fusion system derives its energy by emission of light quanta, it is a fusion-photon system.

ROCKET, RAM. An integral **Jato-ramjet** combination in which the rocket is utilized for obtaining operating speed for the ramjet.

ROCKET RAMJET. A ramjet having a rocket attached to it, usually mounted concentrically within the ramjet duct, the rocket being used to bring the ramjet up to the necessary operating speed. Sometimes called (with a shift in emphasis) a "ducted rocket."

ROCKET SHIP. (1) An aircraft, space ship or other flying vehicle using **rocket propulsion** for its main or only source of motive power, usually considered to be man-carrying. (2) A sea vessel equipped with rocket **launchers** and rocket ammunition.

ROCKET SLED. A sled propelled along a fixed track by rockets to permit acceleration and/or high speed tests, (e.g., **smart**, **snort**).

ROCKET, SOUNDING. A meteorological **rocket** used to gather atmospheric data at various altitudes.

ROCKET THRUST. The thrust of a rocket engine or rocket motor. (See **jet thrust**.)

ROCKET TUBE. (1) A **launching tube** for rockets. (2) A tube or nozzle through which rocket gases are ejected.

ROCKET VEHICLE. A vehicle propelled by a **rocket engine**.

ROCKETRY. (1) The science or study of **rockets**, embracing theory, research, development, and experimentation. (2) The art and science of using rockets, especially rocket ammunition, either on the ground or in the air.

ROCKOON. A balloon-supported and -launched rocket used for high altitude research. **Deacon** rockets are lifted by a **Sky-hook** balloon to high altitudes, where the instrumented rocket is then fired to still higher altitudes. (See illustration facing Page 378.)

ROENTGEN. The absolute unit of x- or gamma-ray dosage used for measuring radiation exposure. It is the quantity of radiation which, when secondary electrons are fully used and the wall effect of the chamber is avoided, produces in one cubic centimeter of atmospheric air at zero degrees Centigrade and 760 millimeters of mercury pressure, such a degree of conductivity that one electrostatic unit of charge is measured at saturation current.

ROENTGEN EQUIVALENT, MAN (REM) (A PROPOSED UNIT; PARKER). The dose of any ionizing radiation that will produce the same biological effect as that produced by one **roentgen** of high voltage x-radiation.

ROENTGEN EQUIVALENT PHYSICAL (REP) (A PROPOSED UNIT; PARKER). A unit proposed to apply to statements of dose of ionizing radiation not covered by the definition of the **roentgen**. It has been variously defined as the dose which produces energy absorption of 83 ergs per gram of tissue or 93 ergs per gram of tissue. The actual energy absorption in tissue per roentgen is a function of the tissue composition and of the wavelength of the radiation, and ranges between 60 and 100 ergs per gram.

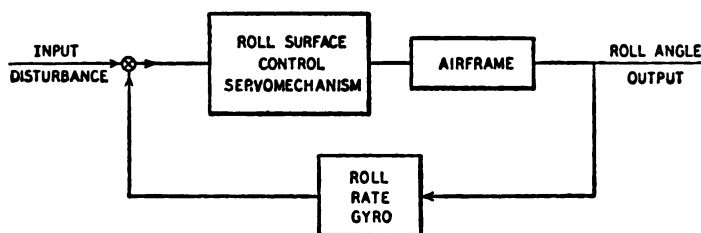
Various authors have used the term roentgen equivalent or equivalent roentgen, basing the equivalence on energy absorption by air, or on the number of ion pairs produced in air by one roentgen of x-rays, or on the energy absorption in tissue from one roentgen of x-rays, or on the ionization produced in a small air cavity by one roentgen of x-rays. The magnitude of all these units is the same within about 10 per cent, in terms of energy absorbed per gram of tissue.

ROENTGEN RAYS. X-rays.

ROLL. An angular displacement about an axis parallel to the longitudinal axis of a missile or vehicle. The angle of roll is the angle which the missile has rotated about its longitudinal axis as measured from some reference plane (this is the horizontal for aircraft). Roll is positive when clockwise as viewed from the tail of the missile. Roll is normally an unintentional rotation of the missile. "Spin" is a roll motion executed intentionally, usually for purposes of stability.

ROLL CAPTURE. Missile flight paths which do not require initial roll stabilization may require a period of time to roll-stabilize. Proper roll orientation, which permits guidance signal decoding, is termed roll capture.

ROLL CONTROL. Missiles are stabilized in appropriate axes to permit resolution of guidance signals. Intelligence is obtained from a reference system such as gyros (free; rate or in combination with networks) and control is obtained from aerodynamic surfaces (separate rollers, differential motion of wing or tail superimposed on pitch and yaw motions); or from gimbaled rocket engines operating differentially. (See figure.)



Roll control block diagram.

ROLLING RESISTANCE (OR FRICTION).

In the rolling of a wheel on a plane surface there is some distortion of the two surfaces in contact due to the normal force between the surfaces. Such distortion smears out the ideal line contact and effectively introduces a force with a component in opposition to the motion. This component of force is called the rolling resistance or friction F_r and is proportional to the normal force N . A coefficient of rolling resistance or friction u_r can be defined by $u_r = F_r/N$, where F_r can be determined experimentally by observing the deceleration on a horizontal surface.

ROMOTAR. A measuring system similar to **Doran**, but fewer modulating frequencies. It obtains direct slant range by employing a ground station receiver located at the same point as the transmitter.

RONCHI PHOTOGRAPHY OF SHOCK WAVES.

A modification of the **schlieren** technique, permitting the qualitative estimation of fluid densities. Neither **schlieren** nor direct-shadow techniques give a means for measurement of density. In the Ronchi system a uniform grid of parallel wires is introduced near the focus of the **schlieren** system.

The parallel wires and the spaces between them are equal. They suppress alternate light rays to form the image in alternate light and dark stripes. When the density of the medium is the same throughout, the dark lines are straight and parallel. Changes in density cause corresponding deflections.

ROOT CHORD. The chord of a wing at its root.

ROPE. Reflectors of electromagnetic radiation consisting of long strips of metal foil. A small parachute or other device may be attached to each strip to reduce the rate of fall. (See **reflector**, **confusion**.)

ROSEBUD. A kind of airborne radar beacon used in radar control and IFF.

ROTARY JOINT. A joint connecting an immobile section of a **waveguide** or **coaxial line** to a section which must be free to turn. Since reliable, current-conducting sliding-contacts are difficult to maintain, one or more half-wavelength short-circuited lines are usually incorporated in the joint in such a manner that the actual point of sliding contact is at or near a current minimum.

ROTATOR. In **waveguides**, a means of rotating the plane of polarization. This may be done very simply in the case of a rectangular guide by twisting the guide itself.

ROTI (RECORDING OPTICAL TRACKING INSTRUMENT). Field instrumentation equipment for recording missile position by means of long focal-length telescopes and a camera.

ROTOCHUTE. A device to induce high drag when deployed from a flight vehicle. It employs auto-rotating blades as distinct from a fabric canopy as used in parachutes.

ROTOR. The rotating portion of a **dynamo** or of any other machine, such as a **centrifuge**. (See also **generator**, **electrical**.)

ROVER. An atomic rocket project under development at the Los Alamos Scientific Laboratory of the Atomic Energy Commission.

R.P. 3.0. A British air-to-ground missile carrying 60 pounds of high explosive in a 5 foot long, 3 inch diameter, four-finned air-frame. The propulsion system was a solid motor using a stick of cruciform cross-section cordite. Velocity attained was 1600 feet per second. The missile was equipped with a 25 pound armor-piercing warhead.

RP-70. A U.S. rocket missile developed following World War II. It was a high wing monoplane with a cigar-shaped fuselage. The wing had a swept-forward edge and straight trailing edge. The vertical stabilizer extended both above and below the fuselage, with the longer fin below. At the tip of the bottom fin, a swept leading-edge, and straight trailing-edge horizontal stabilizer was mounted. Four canard fins behind the nose gave control. Speed was Mach 0.9 at 50,000 feet. It was a solid rocket weighing about 300 pounds, 9 feet long.

RP-76. A U.S. Army high altitude rocket propelled drone target for the **Nike** missile. It was a 300 pound plastic vehicle using an Aerojet 35 pound thrust solid propellant rocket.

RP-77DL. A U.S. Army turboprop drone developed by Radioplane Division of Northrop Aircraft. It was powered by a Boeing 502-10E free turbine driving a propeller.

RSO. Range Safety Officer.

Ru. Ruthenium.

RUBIDIUM. Metallic element. Symbol Rb. Atomic number 37.

RUDDER. A hinged or moveable **airfoil** designed to cause a yawing moment on an air-frame.

RUDDEVATORS. A pair of V-shaped tail surfaces combining the functions of **rudder** and **elevator**.

RUGGEDIZATION. A technique used to improve the ability of a device or equipment to withstand a severe environment.

RUHRSTAHL X-4. A German air-to-air missile developed during World War II. It weighed 132 pounds, carrying 44 pounds of payload. It was 6½ feet in length and 9 inches in diameter. It had four swept back wings, and was propelled by a liquid propellant system, using nitric acid for an oxidizer.

RUHRSTAHL X-7. A German two-stage, solid propellant rocket of approximately 25 pounds total weight, carrying 14 pounds of propellant and 5 pounds of payload. It was 2½ feet in length and 5½ inches in diameter.

RUMBLE. A form of combustion instability, especially in a liquid-propellant rocket engine, characterized by a low-pitched, low-frequency rumbling noise; the noise made in this kind of combustion.

RUTHENIUM. Metallic element. Symbol Ru. Atomic number 44.

R/V. Re-entry Vehicle.

RVA-10. A small solid propellant rocket developed by the General Electric Company as part of the **Hermes** Project. The RVA-10 project was a joint Army Ordnance-General Electric Corporation-Thiokol Chemical Corporation project conducted at the Joint Long Range Proving Ground, Florida (later designated the Air Force Missile Test Center).

S

S. (1) Second (*s*). (2) Scattering coefficient (turbidity) (*s*). (3) Solubility (*s* or *S*). (4) Specific surface (*s*). (5) Area (*S*). (6) Acoustic condensation (*s*). (7) Exponential compressibility (*s*). (8) Cross section (*s*). (9) Elastance, or reciprocal capacitance (*S*). (10) Action (*S*). (11) Displacement (*s*), linear displacement (*s*). (12) Total entropy (*S*), entropy per atom or molecule (*s* or *s_m*), entropy per unit mass (*s*), entropy per mole (*s*, *S* or *S_M*). (13) Length of path or arc (*s*). (14) Slip in electrical machinery (*s*). (15) Stopping power (*S*), mass stopping power (*S_m*), linear stopping power (*S_l*), atomic stopping power (*S_a*). (16) Optical object distance (*s*). (17) Optical image distance (*s'*). (18) Sensitivity of phototube (dynamic, *s*) (static, *S*). (19) Sulfur (*S*). (20) Area of stream tube (*S*). (21) Flame speed (*S*).

S AND A. Safety and Arming Mechanism.

S BAND. A radio-frequency band of 1,550 to 5,200 megacycles with wave lengths of 19.35 to 5.77 centimeters respectively.

SAB. Scientific Advisory Board.

SABIN. An acoustic unit of equivalent absorption equal in its absorbing effect to 1 sq ft of a completely absorbing surface; i.e., one that does not reflect sound waves.

SABOT. A thrust-transmitting attachment which serves as a gas seal for the propellant gas, and which positions and drives a projectile in the bore of a gun or tube.

SAC. Strategic Air Command; Offut Air Force Base; Omaha, Nebraska.

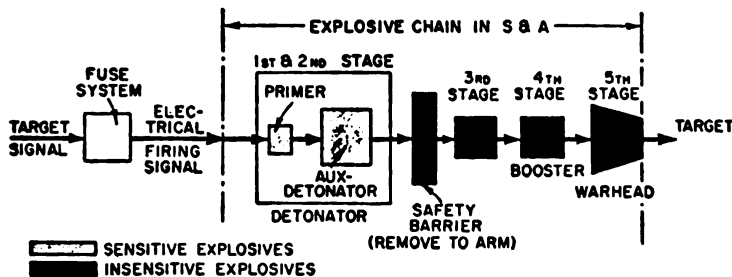
SADDLE POINT. A point (x_0, y_0) on a surface $f(x, y)$ where $f(x, y_0)$ is a maximum at $x = x_0$ and $f(x_0, y)$ at the same time is a minimum at $y = y_0$. A familiar example is the hyperbolic paraboloid, which has a saddle point at the origin if its standard equation is taken as $x^2/a^2 - y^2/b^2 = 2cz$. A person walking toward the origin in the *XZ*-plane would be ascending a mountain peak while he would be descending into a valley if he walked in the *YZ*-plane. (Also called a minimax or a col.)

SADIC. An analog-to-digital converter manufactured by Consolidated Electrodynamics Corporation, Pasadena, California. The instrument is in use at the Naval Air Missile Test Station, Point Mugu, California.

SAF. Secretary of the Air Force.

SAFE-TIME. The time during which the **Safety and Arming Mechanism** is in the unarmed condition, i.e., prevents warhead detonation by fuze action. The period during which warhead detonation cannot occur by fuze action.

SAFETY AND ARMING MECHANISM (S AND A). A device to interrupt the functional path between fuze and warhead until after proper launching has taken place, and until the missile has passed beyond nearby friendly forces; arming consists of completing



Explosive amplifier chain provided by S & A.

the functional path at the proper time. (See figure.)

SAFETY FACTOR. (1) In structural design, the ratio of **ultimate load** to **limit load**. (2) The extent of a unit's capacity to withstand loads or other inputs in excess of those normally expected to be applied.

SAFETY FUSE. **Bickford Fuse.**

SAGE. **SemiAutomatic Ground Environment.**

SAGITTARIUS. (The archer.) This large **constellation** is the ninth sign of the **zodiac**. Lying as it does in a particularly rich portion of the milky way, it contains a large number of star **clusters** and gaseous **nebulae** visible in a moderate-sized telescope. From the large number of faint stars, **cepheid** variables, and globular clusters that seem to congregate in this region, it seems highly probable that the stellar **galactic** system has its greatest extension in this direction. Long-exposure photographs indicate that large numbers of dark or obscuring nebulae lie in this portion of the milky way.

SALVO FIRE. The launching of guided missiles simultaneously in groups. If the overall reliability of a missile is 33% for example, it does not follow that only three missiles are needed to insure a hit. Many salvos will not hit the target, while others will hit twice or even three times, assuming that three missiles are fired in each salvo. The probability of success of a salvo of n missiles is given by:

$$P_{salvo} = 1 - (1 - P_{overall})^n$$

SAM (SURFACE-TO-AIR MISSILES). Missile, ground-to-air; missile, guided; model designation.

SAM-A-7. Army SAM #7, the Nike.

SAM-A-25. Army SAM #25, the Nike-ajax.

SAM-N-6. Navy SAM #6, the Talos.

SAM-N-7. Navy SAM #7, the Terrier.

SAMARIUM. Rare-earth element. Symbol Sm. Atomic number 62.

SANAPHANT. Phantastron.

SANATRON. Phantastron.

SANDIA BASE. The Sandia Corporation; Division of Western Electric; Albuquerque, New Mexico.

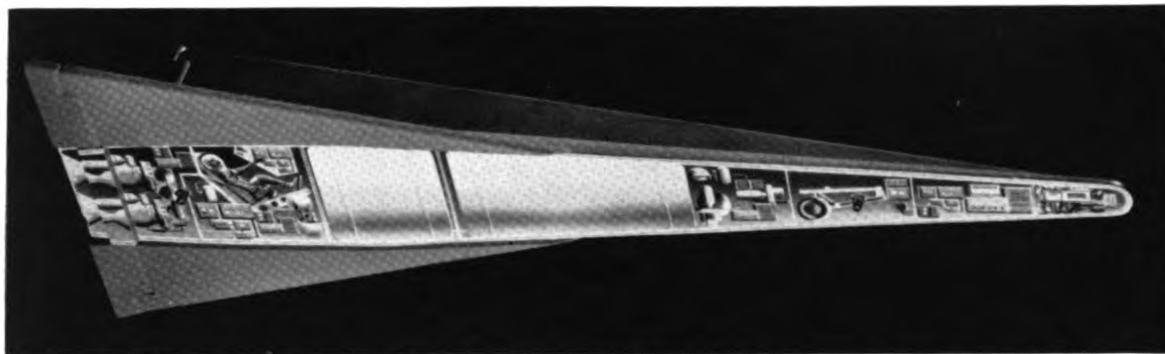
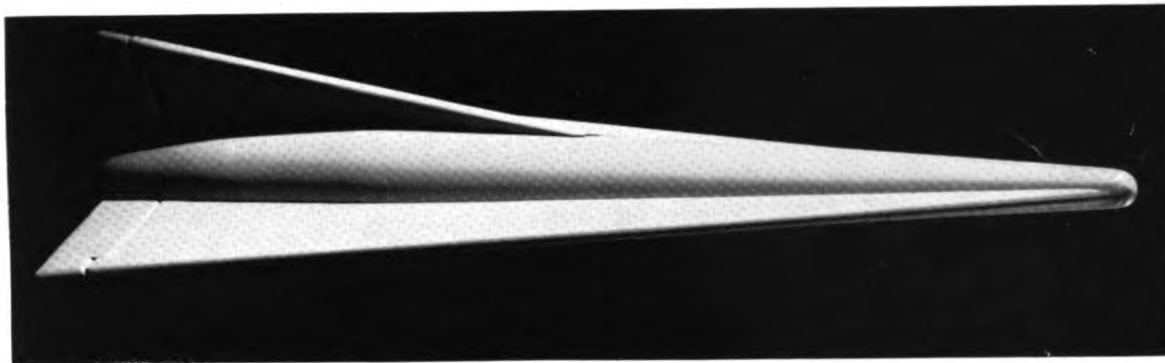
SARA. An abbreviation for Ship Angle and RAnge.) It is a type of single station, precision, ship location gear for use at greater than line-of-sight distances. It was developed by the RCA Missile Test Project Systems Engineering Section at Patrick Air Force Base, Florida.

SARAH. A combined name from Search and Rescue and Homing. It is the name of a British electronic beacon and receiver system used to locate downed flyers. The aviator activates a small beacon carried in his life jacket. Search aircraft are equipped with homing type receivers. The equipment operates on a tunable frequency in the vicinity of 100 megacycles per second. It is also used to locate missiles or subsystems thereof, e.g., **Jupiter** nose cones, when these have fallen into the sea.

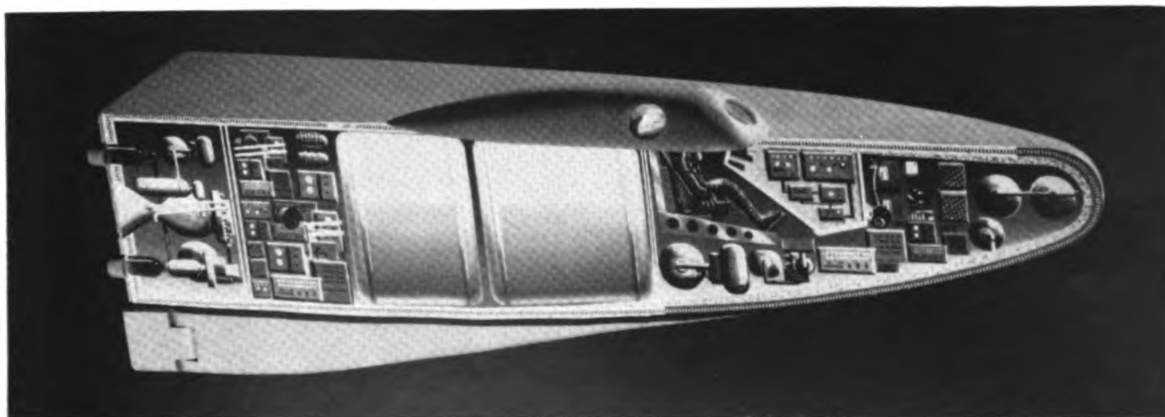
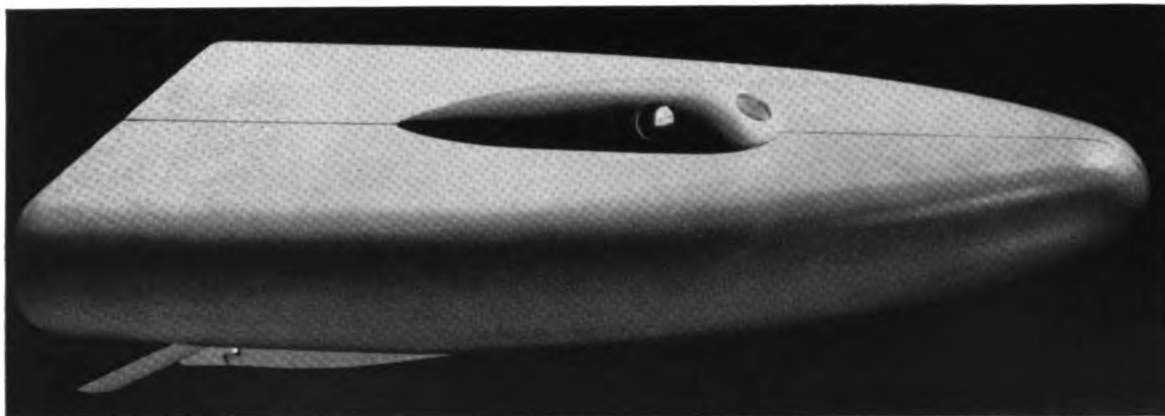
SAROS. The fact that eclipses occur in periodic intervals was known to the ancient Chaldeans, and probably even in prehistoric times. This period of 18 years, 11 $\frac{1}{4}$ days (10 $\frac{3}{4}$ days if there happen to be 5 leap years in the interval) is known as the Saros. If an eclipse should occur on January 1st, 1967, at noon, another similar eclipse would occur on January 12th, 1985, at eight o'clock in the evening. The eclipse would not occur at the same point on the earth but would be about 8 hours farther west in **longitude**.

During the course of a Saros there are about 29 lunar and 41 solar eclipses, each repeated during the next Saros, but not at the same portion of the earth.

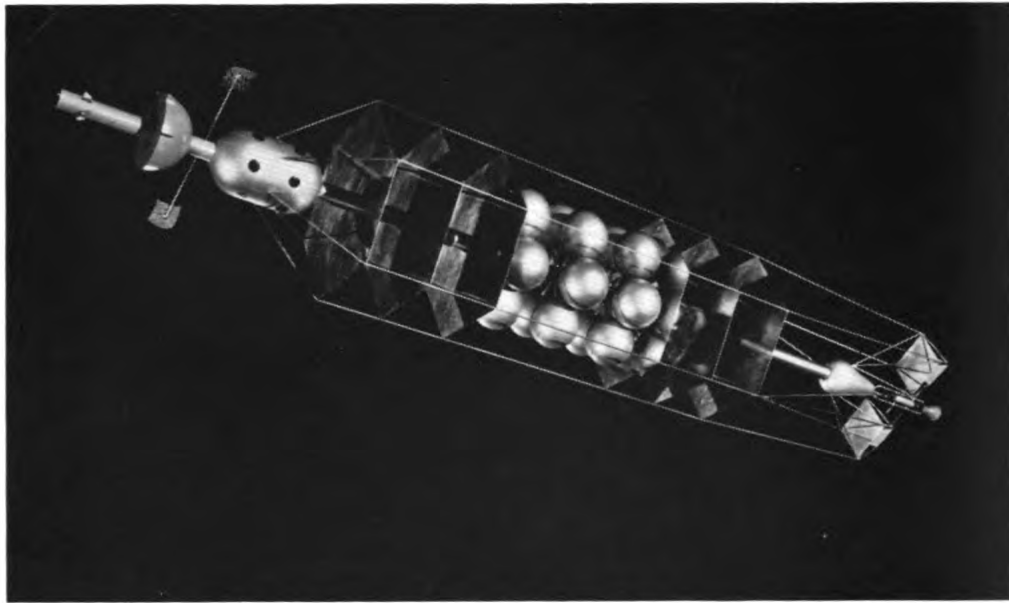
SATELLITE. (1) A space vehicle which orbits a celestial body, e.g., Earth, in an elliptical path. (2) The term satellite is usually reserved in astronomy for small planet-like objects that are revolving about the individual **planets** in orbits. The **moon** is the satellite of the earth and has been known from remotest antiquity. The names and dates of discovery of the other satellites of the **solar system** will be found in the table on page 540. In this table there will also be found other data relative to the satellites. The definitions of the various column headings will be found elsewhere in this work. Further



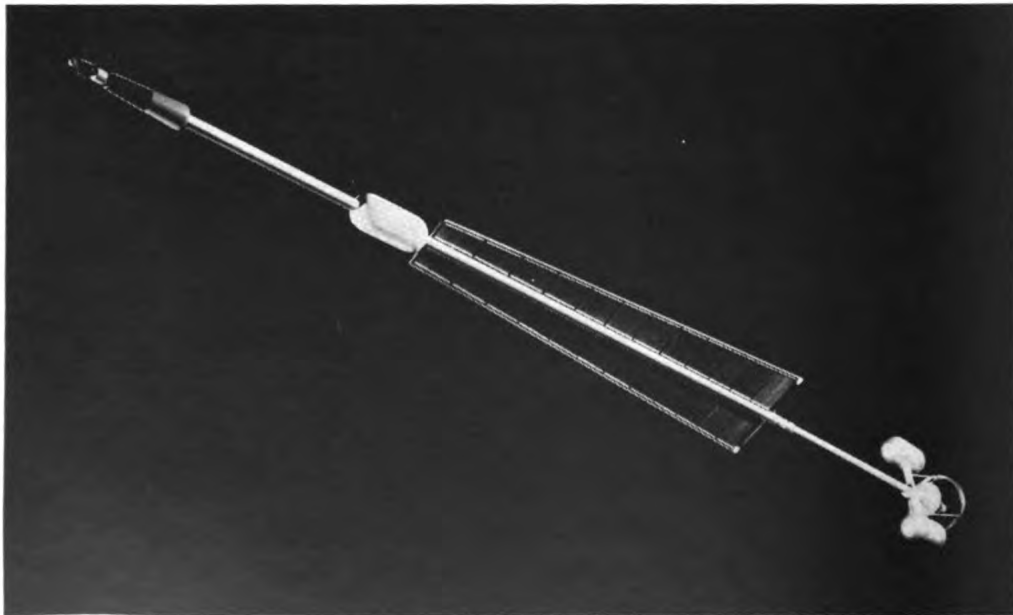
An artist's sketch of the DELTA-WING GLIDER, designed for a possible space vehicle of the future. (NASA Photograph)



An artist's sketch of the BOAT-SHAPED GLIDER, designed for a possible space vehicle of the future. (NASA Photograph)



An artist's sketch of the NUCLEAR ROCKET, designed for a possible space vehicle of the future. (NASA Photograph)



An artist's sketch of an ELECTRICAL PROPULSION VEHICLE, designed for a possible space vehicle of the future. (NASA Photograph)

information regarding the different satellites will be found in the articles on the individual planets.

Satellites serve a useful purpose to astronomers since the mass of a planet can be determined accurately only if the planet has a satellite. By application of the rigorous expression for the harmonic Keplerian law of planetary motion the mass of any planet and satellite may be found in terms of the mass of the earth-moon system after the distance of the planet from the satellite and its period of revolution are known. The problem of the determination of the masses of the satellites themselves is a more difficult problem. The mass of the moon can be determined in terms of the earth's mass by means of the so-called barycentric parallax. Approximate values of the masses of the satellites or Jupiter can be obtained by the mutual perturbations which they exert on each other. In the case of Saturn the masses of the satellites may be approximately determined from their mutual perturbations and an approximate check is provided by the positions of the divisions in the rings.

The three outer satellites of Jupiter, the outer satellite of Saturn, the five satellites of Uranus, and the inner satellite of Neptune all revolve about their primaries in the retrograde sense, i.e., in the direction contrary to that in which all other planets and satellites are revolving and rotating. This retrograde motion can be completely explained on the basis of modern celestial mechanics.

The influences which satellites exert on their primaries are very slight. The tidal forces which they exert have some slight effect upon the rotation periods of the primaries but such effects are so small as to be beyond observational measurement. The tidal effects which the planets exert upon the satellites, on the other hand, are in many cases so large that the satellites rotate in approximately the same period as that in which they revolve.

The question as to the origin of the satellite systems is still unanswered. The systems bear so much resemblance to the solar system itself that there is the suggestion that their evolutionary process may be the same as that discussed under the topic of solar system, but there are many objections to such a theory. Since the moon is the largest satellite in the solar system in comparison with its primary, and also being larger in proportion to the

earth than any other planet is to the sun, it presents some very particular problems. If they ever formed one single mass, that mass must have been rotating with a period of approximately 4 hours, and have been greatly flattened at the poles. Such a mass would tend to break up under the influence of the rapid rotation, but would remain intact unless some external force was present. Such a force is found in the tidal effects of the sun, and the earth-moon system may have been formed by the breaking up of a large parent mass. However, the alternative hypothesis that the earth and moon were formed as two separate bodies at the time that the solar system was formed cannot be disproved.

SATELLITE, ARTIFICIAL. Research with radiosondes and high altitude balloons and rockets has proved the value of the information to be obtained by any means of placing instruments at high altitudes under conditions that permit them to transmit their observations, or sometimes to record them so they are not destroyed on the return of the carrying device. A logical extension of this technology is the artificial satellite, a device designed to be propelled far enough from the earth so that it moves in an orbit about the earth. Before discussing the stability and lifetime of such orbits, the various types of data to be obtained by them will be discussed.

A satellite can be provided with instruments to record continuously the ultraviolet and x-ray radiation from the sun, at distances beyond those at which the earth's atmosphere absorbs them appreciably. A satellite can also measure the earth's magnetic field at high altitudes, the intensity of meteoric dust, and electromagnetic and corpuscular radiations, especially cosmic rays. The study of the latter, in particular, has disclosed significant variations with latitude, with longitude, as well as with altitude, that are not fully investigated or understood. The more complete cosmic ray data obtainable at great distances from the earth, and all around the earth, will help to answer, it is hoped, many questions about cosmic rays such as the effect upon them of variations in solar activity. A satellite can also obtain magnetic data useful in solving the problem of magnetic storms. Even in the field of relativity a satellite may contribute valuable data, based upon very accurate measurements and comparisons of the time kept by

THE SATELLITES OF THE SOLAR SYSTEM

NUMBER, NAME AND DATE OF DISCOVERY	MEAN DISTANCE IN MILES FROM PRIMARY	SIDEREAL PERIOD		APPARENT STELLAR MAGNITUDE	ON SCALE MOON = 1	
		DAYS	HOURS		Diameter	Mass
SATELLITE OF THE EARTH						
Moon.....	238,857	27	7.720	-12.3	2160 mi.	
SATELLITES OF MARS						
1 Phobos.....1877	5,826	0	7.654	11.5	0.0043	
2 Deimos.....1877	14,580	1	6.299	13.0	0.0023	
SATELLITES OF JUPITER						
5 Fifth.....1892	112,600	0	12	13	0.0460	
1 Io.....1610	261,800	1	18	5.5	1.0731	1.09
2 Europa.....1610	461,600	3	13	5.7	0.9062	0.65
3 Ganymede.....1610	664,200	7	04	5.1	1.4816	2.10
4 Callisto.....1610	1,168,700	16	17	6.3	1.4902	0.58
10 Tenth.....1938	7,450,000	264		18		
6 Sixth.....1904	7,490,000	266		13.7	0.0374	
7 Seventh.....1905	7,680,000	276		16	0.0115	
12 Twelfth.....1951	13,000,000	625		19		
11 Eleventh.....1938	14,000,000	692		18		
8 Eighth.....1908	14,600,000	739		16	0.0072	
9 Ninth.....1914	14,700,000	750		18	0.0072	
SATELLITES OF SATURN						
7 Mimas.....1789	115,300	0	22.618	12.1	0.1870	0.0005
6 Enceladus.....1789	147,800	1	8.885	11.6	0.2445	0.002
5 Tethys.....1684	183,000	1	21.307	10.5	0.3740	0.008
4 Dione.....1684	234,400	2	17.686	10.7	0.3452	0.014
2 Rhea.....1672	327,300	4	12.420	10.0	0.5034	0.033
1 Titan.....1655	758,800	15	22.691	8.3	1.2083	1.86
8 Hyperion.....1848	919,700	21	6.640	13.0	0.1438	0.002
3 Iapetus.....1671	2,210,000	79	7.940	11.0	0.5178	0.08
9 Phoebe.....1898	8,034,000	550		14.5	0.0575	
SATELLITES OF URANUS						
5 Miranda.....1948	81,000	1	9.933	17.0		
1 Ariel.....1851	119,100	2	12.489	15.2	0.2589	
2 Umbriel.....1851	165,900	4	3.460	15.8	0.2014	
3 Titania.....1787	272,200	8	16.941	14.0	0.4891	
4 Oberon.....1787	364,000	13	11.118	14.2	0.4315	
SATELLITES OF NEPTUNE						
1 Triton.....1846	219,800	5	21.044	13.6	1.4384	
2 Nereid.....1949	3,440,000	359	10.0	19.0	0.093	

General Designation	Sputnik I	Sputnik II	Explorer I	Vanguard I	Explorer III	Sputnik III
Astron. Code Name	1957 α	1957 β	1958 α	1958 δ	1958 γ	1958 ϵ
<i>General Data</i> Launching date	October 4, 1957	November 3, 1957	January 31, 1958	March 17, 1958	March 26, 1958	May 15, 1958
Launching time (local)	not disclosed	not disclosed	12:46 P.M.	9:36 A.M.	2:37 P.M.	not disclosed
Launching site	near Caspian Sea	same (?)	Cape Canaveral, Fla.	Cape Canaveral, Fla.	Cape Canaveral, Fla.	near Caspian Sea (?)
Satellite weight (lb)	184	1,120 w. empty st. 3	33.5 w. empty st. 4	3.26	3:15 w. empty st. 4	2,925
Payload weight	not disclosed	not disclosed	14.95			not disclosed
Shape	sphere	cone	cylinder 2.82 ft. without st. 4	sphere	cylinder	cone
Length	—	5.5 ft. without st. 3	(6.66 ft. total)	—	Like Explorer I	11 ft 5.6 in.
Diameter	23 in.	approx. 39 in. at base	6 in.	6 in.	6 in.	5.12 ft at base
Transmitter life (days)	21	5				
Orbital life	90 ^d	161 ^d	5-10 ^y (estimated)	200 ^y (estimated)	4-6 mo. (estimated)	6 months (estimated)
Date of re-entry	St. 3: Dec. 1, 1957 Sat.: Jan. 4, 1958	April 13, 1958				
<i>Initial Orbit Values</i> Period (min.)	96.2	103.6	115.27	134	115.87	105.95
Perigee altitude (n. mi.)	130	121.5	195.5	350.5	100.11	130
Apogee Altitude (n. mi.)	500	1,085	1,384	2,140	1,285	1,085
Orbital inclination	61° 47'	~65°	~34°			65°
Semi-major axis (n. mi.)	3,759	4,047	4,234	4,689	4,137	4,051
Eccentricity	0.05	0.117	0.14	0.192	0.143	0.128
Latitude of perigee						
Longitude of ascending node						
Perigee velocity (ft/sec)	26,180	26,750	27,000	27,600 (estimated)	27,680	26,410 (estimated)
Apogee velocity (ft/sec)	23,600	22,000	20,350	17,600 (estimated)	19,760	20,400 (estimated)
<i>Dynamic Orbit Values</i> Retrograde nodal motion (1/day)	2° 33' \pm 5' ¹⁾					
Rate of decrease of period (1/day)	2.2 \pm 0.1 sec					
<i>Equipment</i> No. of transmitters	2		2 (3.95 lb)	2	2	not disclosed
No. of antennas	4	not disclosed	4	6	not disclosed	not disclosed
Power supply	batteries	batteries	batteries	batteries + 6 solar batteries	batteries	batteries + solar batteries
Transmitter frequency	20.005	20.005 (0.3 sec period) 40.002 (continuous)	108.00/108.03	108.00/108.03	108.00/108.03	20.005 (· — · · code)
Transmitter power (watt)	1	1	0.06/0.01	0.01/0.005	0.06/0.01	
Instrumentation and/or measurements	Magnetometer Temp. (?) Press. (?)	Dog Laika Pressurized cabin Accessories Food plus Pressure measurement Temperature UV-radiation Cosmic radiation Micrometeorites (?)	Micrometeorite erosion gauges. External temp. gauges (rear and front). Internal temp. gauge (behind hi-power transmitter). Micrometeorite impact microphones Cosmic ray counter		Micrometeorite erosion gauges Cosmic ray counter (more extensive package than No. 1) External temp. Play back recorder	Pressure Atmospheric composition Concentration of positive ions Electrical charges in Satellite Earth's electric field Earth's magnetic field Solar corpuscular radiation Primary cosmic radiation Distribution of protons and heavy nuclei in cosmic primaries Micrometeorites

a satellite clock. The satellite can also obtain data on the **figure of the earth**, which is of great value in accurate predetermination of missile and space ship landing points.

The satellite must, of course, be launched from the earth by devices that impart sufficient velocity so that it reaches its desired orbit. This is accomplished by the principle of multi-staging. (See **Explorer**, **Vanguard**, **Sputnik**.) (See also Table on Page 541.)

SATELLITE BODY. A small body describing an orbit in a **central force field** and having a mass negligible in relation to the mass of the **central body**. (See also **infinitesimal body**.)

SATELLITE, EARTH. A satellite orbiting the earth, as the moon or **Explorer IV**.

SATELLITE ELEMENTS. A series of quantities, numbering at least six, which are used to define the orbit and motion of an artificial satellite. In the following discussion, this satellite is assumed to be an earth satellite. Therefore, while the orbital elements are similar in kind to those discussed in the article on planetary motion, they differ in that the reference system is not based upon the sun, but upon the earth, and measurements are made from the equatorial plane of the earth. For this reason, orbital elements for artificial earth satellites are sometimes called equatorial elements.

A second plane from which earth-satellite orbital measurements are made is the orbital plane of the satellite itself. All satellite orbital measurements are made in these two planes. These elements are listed in the table below, and their geometrical significance is shown in the figures.

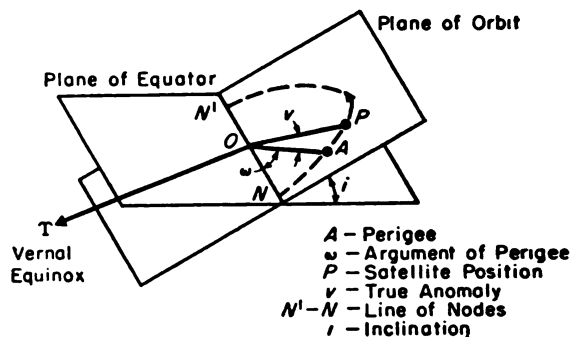


Fig. 1. Satellite elements. Elements of a satellite orbit.

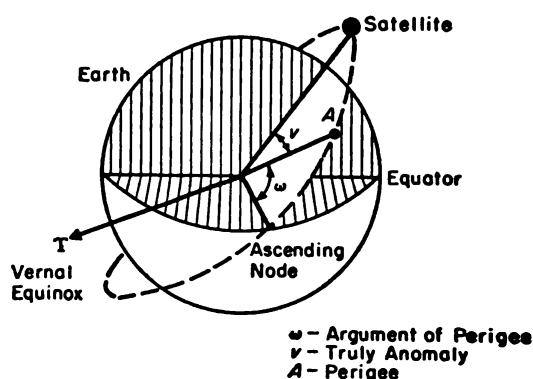


Fig. 2. Satellite elements. Typical satellite orbit.

satellite, and hence its various components, is not constant. They are, however, established by the period of the satellite, when its orbital elements have been defined.

The angle of inclination, which is sometimes called the inclination, determines the maximum north and south latitudes reached by the satellite, and consequently, the extent of the earth's surface observable by the satellite. The angle of inclination is defined as the angle

ORBITAL ELEMENTS OF EARTH SATELLITE

ELEMENT	PURPOSE
Inclination, (i)	Sets orbital plane against equator
Right ascension of the ascending node, ($\alpha\Omega$) or (Ω)	Sets orientation of the orbital plane in the solar system
Argument of the perigee, (ω)	Orients the orbit within the orbital plane
Eccentricity, (e)	Defines the form of the orbit
Semimajor axis, (a)	Defines the size of the orbit
Time of perigee passage, (T)	Defines the motion in the orbit

The elements of an artificial satellite are not constant. They are taken at an arbitrary time, which should be included in the statement of data. Moreover, the velocity of a

between the plane of the satellite's orbit and that of the earth's equator. It is also the angle between the direction of the earth's axis and that of the axis of the orbit of the satellite.

The maximum angle of inclination is obviously 90° . Beyond this point the orbital travel is westward rather than eastward. Since satellites traveling westward are moving in a direction opposite to the rotation of the earth, they are said to have retrograde orbits. Orbits based upon an angle of inclination less than 90° for eastward travel, which are therefore in the same direction as the rotation of the earth, are called direct orbits.

The satellite orbital element called right ascension of the ascending node is defined as the angle at the center of the earth from the vernal equinox to the ascending node of the satellite, measured in the equatorial plane in an easterly direction. This element fixes the aspect of the orbital plane of the satellite, that is, the direction the satellite faces in the solar system.

The nodes are the points at which the satellite orbit pierces the equatorial plane of the earth. The node from which the satellite travels toward the north is called the ascending node; while the node from which the satellite travels toward the south is called the descending node. The line joining the two nodes is the intersection between the plane of the earth's equator and the plane of the satellite orbit. It is called the line of nodes. The ascending node is used for primary reference: thus the right ascension is the right ascension of the ascending node.

The right ascension of the node decreases as the satellite moves, and during one revolution it is shifted westward. This motion, which is opposite to that of the earth, is called the regression of the nodes.

The shape and size of the elliptical orbit of a satellite are defined by the eccentricity and the semimajor axis of the ellipse. Its position in the orbital plane is defined by the argument of the perigee, which is the angle between the ascending node and the perigee measured at the focus of the orbital ellipse, in the plane of the orbit and in the direction of motion of the satellite. The focus of the orbital ellipse is the center of the earth. Because the figure of the earth is not truly spherical, the satellite perigee is not fixed in space but advances steadily. The motion is called the advance of the perigee or sometimes, motion plus. (The term motion minus is the regression of the nodes).

In view of the constant change in the elements of the orbit of the satellite, they must be

defined at a particular time, as stated earlier in this article and this time is commonly called the epoch. The epoch may be expressed in reference to, or as identical with, the universal date-time of passage of the perigee point. However, the time of passage through the ascending node, or through some other point, may also be used. In such cases the actual point of reference in the orbit is established by the true anomaly, which is the angle between a line from the perigee to the center of the earth, and a line from the center of the earth to the satellite at a given instant.

Another position reference that may be used as an epoch point is the mean anomaly at epoch, which is defined by the relationship, $M = n(t - T)$, where n is the mean motion and is equal to $2\pi/\text{period}$, t is a given time, and T is the time of perigee passage. Therefore, the mean anomaly at epoch is an angle ranging from zero at perigee to a value of 360° in each orbital period.

SATELLITE, FOIL. An artificial satellite constructed of aluminum foil sandwiched to a sheet of plastic film. For launching, such spheres are folded into a small package, together with a more conventional type of artificial satellite. When the latter is hurled into orbit, the foil sphere becomes detached and is inflated by a container of compressed gas; the gas then escapes, leaving the inflated sphere in orbit. The very light weight of large foil satellites, renders them extremely sensitive to low concentrations of air molecules, therefore they are useful for obtaining data on conditions in the upper atmosphere. Their large reflective area also facilitates tracking.

SATELLITE(S), INHABITED, CLASSIFICATION OF. Inhabited satellites can be classified as observational (permanent), temporary establishments for the assembly of astronomical expeditions (orbits of departure), temporary establishments, involving arriving astronomical expeditions (orbits of arrival) and temporary auxiliary establishments for load transfer (auxiliary orbits).

Observational satellites are useful for scientific activities and terrestrial functions, pertaining to the earth as the abode of man. Orbital inclinations with respect to the equator should be high (45 to 75 degrees) for observational reasons. Orbital altitudes should be as

low as permissible (500 to 600 nautical miles), in order to reduce the cost of maintenance from the earth, and to permit maximum utilization of earth or scanning devices.

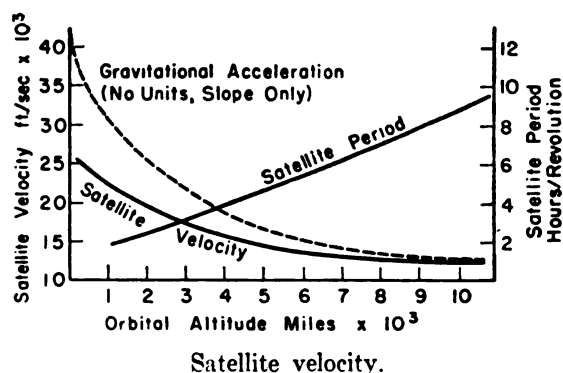
SATELLITE ORBIT. Orbit, satellite.

SATELLITE PERIOD. Artificial Earth satellites do not have one simple period. The period commonly given in non-technical accounts is generally the *sidereal period* or time required for a complete revolution of the satellite in right ascension. There are two other periods of some interest: the *radial anomalistic period*, which is the time from one perigee passage to the next; and the *nodical period*, or time between successive passages of the satellite through the ascending node. These differ from one another by fractions of a minute only.

SATELLITE VEHICLE. An artificial satellite (i.e., a body caused to revolve about the earth). The method originally proposed in the U.S. Earth Satellite Vehicle Program, and which has been followed in the launching of the U.S. *Explorers* and the U.S.S.R. *Sputniks*, is to project a (multistage) rocket to the approximate orbit, to turn it into a plane perpendicular to a projected earth radius and to launch from it a high velocity body, the satellite. If the velocity is of required magnitude, it will then move in an elliptical trajectory around the earth. The permanence of the orbit depends partly upon the influence of the atmosphere which, even though very tenuous at satellite altitudes, exerts a frictional effect.

The required velocity is given, to a first order by the relationship: (See figure.)

$$v = \frac{(g_R R)^{1/2}}{(1 + h/R)^{1/2}}$$



Where v is the satellite velocity, g_R is the gravitational attraction of the earth at the surface, R is the radius of the earth, and h is the height above the surface of the earth. The period of rotation about the earth is given by:

$$T = 2\pi \left(\frac{R}{g_R} \right)^{1/2} \left(1 + \frac{h}{R} \right)^{3/2}$$

Wernher von Braun, Director of Technical Operations of the Army Ballistic Missile Agency at Redstone Arsenal, Huntsville, Alabama, has proposed the use of satellite vehicles as space platforms from which interplanetary voyages could be launched. His space stations would be established at an altitude of 1075 miles in two-hour orbits. These would be assembled in space by workers carried to the assembly point in ferry rockets. The purpose of such stations would be to allow interplanetary departures and arrivals in ships designed for space travel, thus obviating the use of structures designed for atmospheric conditions. The satellite vehicle also would be an excellent platform for observation of the earth and other celestial bodies. It is a first step in astronautics.

SATELLOID. A name coined by Krafft A. Ehrlicke to designate a weakly-powered satellite which would maintain its orbital position by means of internal power. This would operate at a lower altitude than an unpowered vehicle, perhaps 80 miles from the surface of the earth, and in a circular, or nearly circular, orbit. The satelloid concept simplifies to some degree the problem of the manned satellite. A recent discovery of atmospheric atomic oxygen at altitudes of approximately 65 miles may provide the source for propulsive materials required for a satelloid. Aero-bee rocket tests have shown that atomic oxygen exists at these altitudes, which might be used as a high-energy propellant. (See *free radical*.)

SATURABLE REACTOR. An inductive passive element whose impedance may be controlled by regulating the degree of magnetic saturation of a ferromagnetic core.

SATURATE. The overwhelming of defensive firepower by sheer numbers of targets.

SATURATING REACTOR. An inductor (1) operating in *saturation* (5) without independent control means.

SATURATION. The state of being satisfied, or replete, or the action of bringing about that state. Some specific uses of this term apply to a single substance, entity, or region, and others to relations between more than one as: (1) The overwhelming of defensive firepower by sheer numbers of weapons. (2) The overwhelming of any automatic device by excessive inputs. (3) Saturation current is the **ionization current** which results when the applied potential is sufficient to collect all ions. It is the maximum current that will pass through a gas under definite conditions of ionization. It is a measure of the charge carried by the ions produced in each second, and hence may be used as a measure of the **radioactivity** of a substance. (4) Color saturation is the attribute of any color perception possessing a **hue**, that determines the degree of its difference from the achromatic color perception most resembling it. (5) A saturated vapor whose temperature corresponds to the boiling temperature at the pressure existing on it. (6) Magnetic saturation is the maximum **magnetization** (or the maximum permanent magnetization) of which a body or substance is capable. (7) As applied to a **solution**, saturation is the process or condition of dissolving in a **solvent** all of a **solute** which the solvent can absorb, under equilibrium conditions at a given temperature.

SATURN. (For data, see **planet**.) Saturn, the "ringed planet," is the sixth major **planet** in order of distance from the sun and was the outermost planet known to the ancients. In point of size Saturn is the second largest among the planets, having a diameter slightly more than 9 times that of the earth and but slightly less than the diameter of **Jupiter**.

The physical characteristics of the planet itself are approximately the same as those for Jupiter. The low density, high rotation speed, and variation of rotation period with planetary latitude all point to the probability that the solid core of the planet is relatively small and is surrounded by an atmosphere of very great thickness. As in the case of Jupiter, spectroscopic analysis indicates that the **atmosphere** is composed to a large extent of methane with some ammonia. All evidence, both observational and theoretical, indicates the surface temperature of the planet to be in the neighborhood of 123°K. (−238°F.). This low temperature coupled with the lack of oxy-

gen in the planet's atmosphere indicates the impossibility of there being any life on Saturn such as we have on the earth.

To the naked eye, Saturn appears comparable to the brighter stars. In a telescope the planet itself has a belted appearance similar to that of Jupiter, but without as many distinctive surface features as are to be seen on the larger planet. From these semipermanent surface features the rotation period of the planet has been determined and found to be but slightly over 10 hours. There is also considerable evidence that the rotation period varies with planetary latitude, being the shorter at the equator.

Undoubtedly, the most remarkable and best known characteristic of Saturn is the ring system which surrounds the planet. These rings have the appearance of circular disks of paper, pierced with a hole in the center to admit the planet. The rings are parallel to the planet's equator and, since the equator is inclined to the **ecliptic** at an angle of about 28°, the plane of the rings is inclined to the plane of the ecliptic by the same amount. Saturn revolves about the sun with a period of about 29.5 years and twice during this period the plane of the rings passes through the orbit of the earth. The plane of the rings takes nearly a year to pass the earth's orbit and during this period the earth may pass through the plane of the rings either once or three times. At these times the rings are seen edgewise from the earth and appear as thin needles of light extending out from the planet's equator. Intermediate between the passage of the earth through the plane of the rings they "open out" to their maximum angle at which time they appear as an **ellipse** produced by tipping a circle by about 27°, or an ellipse with an apparent width about half its maximum length.

The question of the origin of the ring system of Saturn is still a much debated problem. The two main theories postulate either that a large satellite was "spoiled in the making," or that a large satellite was formed and then exploded under the influence of some unexplained force. (See **Roche Limit**.)

SAWTOOTH WAVE. Wave, sawtooth.

SAW-TOOTH GENERATOR. A neon or thyatron relaxation oscillator or a vacuum tube oscillator providing an alternating voltage characterized by a saw-tooth waveform.

Sb. Antimony.

Sc. Scandium.

SCALE EFFECT. An effect in fluid flow, that results from changing the scale, but not the shape, of a body around which the flow passes. Correction of this effect is by application of the **Reynolds number**.

SCALE FACTOR. (1) In analog computing, a proportionality factor which relates the magnitude of a variable to its representation within a computer. (2) In digital computing, the arbitrary factor which may be associated with numbers in a computer to adjust the position of the radix so that the significant digits occupy specified columns. (3) A measure of the sensitivity or merit of an instrument: e.g., in a galvanometer or similar device it is the ratio of the current through, or the voltage across, the terminals to the deflection.

SCALING LAW. A formula which permits the calculation of a property of a given article based on data obtained from a similar article of different size: (e.g., crater size, nuclear radiation, etc., for a nuclear warhead of any yield from the known values for another yield).

SCANDIUM. Metallic element. Symbol Sc. Atomic number 21.

SCANNER. A device or means for scanning.

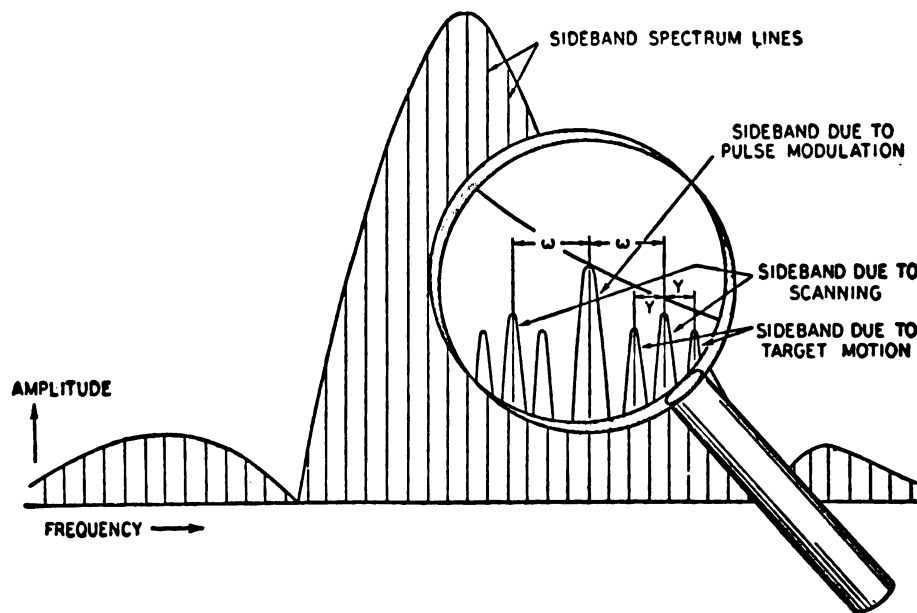
SCAN. To perform the act of scanning.

SCANNING. (1) The action of surveying the sky or any particular airspace by looking successively from one direction to another. Said of pilots or observers seeking out a target or other object, or guarding against surprise. (2) The process of analyzing or synthesizing successively, according to a predetermined method, the light values of television picture elements constituting a picture area. (3) A periodic motion given to the major lobe of an **antenna**, especially a radar antenna. Here the purpose of scanning is to search for a target.

SCANNING ANTENNA MOUNT. A mechanical support for an antenna which provides mechanical means for scanning or tracking with the antenna, and means to readout information for indication and control.

SCANNING, CIRCULAR. Scanning in which the direction of maximum radiation (beam axis) generates a plane or a right circular cone whose vertex angle may approach 180° .

SCANNING, CONICAL. Scanning in which the direction of maximum radiation generates a cone whose vertex angle is of the order of the beam width. Such scanning may be either rotating or nutating, according as the direction of polarization rotates or remains unchanged. (See figure.)



Conical scanning radar spectrum.

SCANNING, INDIRECT. Essentially the same scanning mechanism as flying-spot scanning except that it is accomplished mechanically, as in the older mechanical television systems.

SCANNING, RECTILINEAR. The process of scanning an area in a predetermined sequence of narrow, straight parallel strips.

SCANNING, SECTOR. Circular scanning (see **scanning, circular**) in which but a portion of the plane or flat cone is generated.

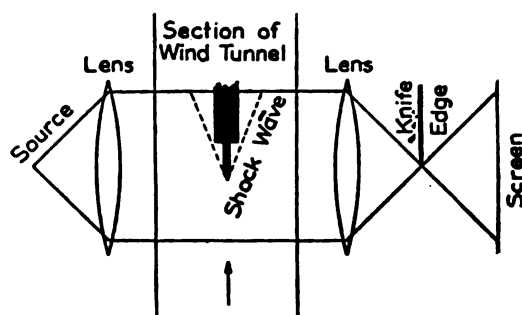
SCANNING, SPIRAL. Scanning in which the direction of maximum radiation describes a portion of a spiral. The rotation is always in one direction.

SCAR. Subcaliber aircraft rocket, used in gunnery training.

SCATTERING. In its general sense, this term means causing the random distribution of a group of entities, or bringing about a less orderly arrangement, either in position or direction. More specifically, the term denotes the change in direction of particles or photons owing to collision with other particles or systems; it may also be regarded as the diffusion of a beam of sound or light (or other electromagnetic radiation) due to the anisotropy of the transmitting medium. For the various kinds of scattering, and the various entities scattered, see the entries which follow.

SCEL. Department of the Army; Signal Corps Engineering Laboratories; Fort Monmouth, New Jersey.

SCHLIEREN. A photographic technique used to record high-speed gas density discontinuities. Gradients or variations in gas



Idealized Schlieren apparatus for observing shock wave in supersonic tunnel.

density, or striae (from the German word). Schlieren are made visible by an optical system which either cuts off or passes a large change in light intensity owing to the slight refraction of the light passing through the gas. This system is often used in wind tunnels making visible turbulence and weak shock waves by showing the first derivatives of gas density directly.

SCHMETTERLING. A German World War II surface-to-air missile. Its official designation was the Hs 117. Overall weight was 981 pounds, of which 165 pounds were propellant and 55 pounds, warhead. Length was 12½ feet and diameter was 14 inches.

SCHMOO PLOTTING. Plots which show the operating margins when the component under test is varied between its upper and lower "end of life" limits, while all other components are at the worst end of the initial acceptance tolerances.

SCHOTTKY EFFECT. Lowering of the surface barrier by an electric field. The lowering of the work function due to an applied accelerating field. It is responsible for a noticeable increase in emission current in vacuum tubes as the applied voltage is increased.

SCHULER PENDULUM. (Earth Pendulum).

SCINTILLATION. (1) A flash of light produced in a phosphor by an ionizing event. (2) The apparent random motion of the center of reflectivity of a target being tracked by a radar, especially a homing radar nearing an intercept.

SCINTILLATION COUNTER. A device consisting of several transparent phosphors together with a photomultiplier tube, which detects ionizing particles or radiation by means of the light flash emitted when the radiation is absorbed in the phosphors.

SCINTILLOMETER. An energy sensitive instrument similar to a photoelectric cell which emits light bursts when activated by a radiation source.

SCOPODROMIC. Of or pertaining to an on the target course; homing, or heading in the sighted direction.

SCORE. Project Score.

SCORPIUS. (The scorpion.) The constellation that is the eighth sign of the **zodiac**. The **constellation** is rather far south for observation in Europe and North America, but is a beautifully grouped constellation presenting more resemblance to the figure for which it is named than is the case with most of the others.

The brightest star in the group Antares (Alpha Scorpii) is one of the most beautiful stars in the sky. It is distinctly reddish in color and gets its name from the fact that it opposes or rivals **Mars**, the red planet, in color. It is the largest star whose diameter has thus far been measured, having a diameter approximately 450 times that of the sun. The star is so large that if it should replace the sun it would extend out beyond the planet Mars.

Beta Scorpii is a fine **double** for an observer with a small telescope with the two components distinctly different in color.

SCORSBY TABLE. A two-degree-of-freedom random motion table used for testing **gyroscope drift**.

SCRAMBLER CIRCUIT. Circuit, scrambler.

SCREAMER. A British (Armstrong-Siddeley) 9500-pound-thrust rocket motor, burning a liquid oxygen-alcohol propellant. Its dimensions are 78 inches in length, 28 inches in diameter and 470 pounds in weight.

SCREAMING COMBUSTION. A combustion instability in jet engines producing relatively high-frequency pressure oscillations and auditory effects.

SCREECHING COMBUSTION. A form of combustion instability, especially in a liquid-propellant rocket engine, occurring at relatively high frequencies and characterized by a harsh, shrill noise; the noise made in this kind of combustion; **screaming combustion**.

SCREEN GRID. A grid placed between a **control grid** and an **anode**, and usually maintained at a fixed positive potential, for the purpose of reducing the electrostatic influence of the anode in the space between the screen grid and the **cathode**.

SCRUB. In missile parlance, a cancelled flight test.

Se. Selenium.

SEA SLUG. British ship-to-air, solid-propellant fleet-defense missile.

SEAC. The name of the computer at the National Bureau of Standards in Washington, D.C.

SEARCH RADAR. A **radar** installation designed to detect and give early warning of the approach of targets. It is not a high precision or high resolution type of **radar**. When targets are located they are "turned over" to other radar sets for fine tracking. It is also called **acquisition** or **surveillance radar**.

SECONDARY EMISSION. This term refers to the result of any of several different processes, in each of which some kind of "primary" emission, when it encounters some form of matter, gives rise to another emission of the same or of different character.

The most familiar example of a secondary emission is the **x-rays**, which have their origin in the impacts of high-speed electrons (cathode rays) upon atoms of matter. The resulting x-rays may themselves act, in turn, as the primary emission and, falling upon solid bodies, cause a secondary x-ray emission. Or they may fall upon fluorescent substance (see **luminescence**) and give rise to a secondary radiation of visible light. X-rays, ultraviolet, or light, falling upon a photosensitive metal, may cause a secondary emission of photoelectrons. The "recoil" electrons from the Compton scattering of x-rays constitute one form of secondary emission.

The most common use of the term denotes the emission of electrons from a solid as the result of the collision of higher energy electrons with the solid.

SECOR (SEQUENTIAL CORRELATION RANGING). A range instrumentation system designed to provide distance and position information. A missile-borne **transponder** is interrogated by a ground station and the answer received by several stations to provide distance data. Angle measurement is provided by phase comparison techniques.

SECRECY SYSTEMS. In much of the two-way radio telephone links it is highly desirable to make the transmission secret. Since the radiated energy may be picked up by any

receiver tuned to its frequency and in its path, the transmission must be altered so it is unintelligible to anyone not having the necessary equipment to restore it to its original form. Not only is the equipment necessary, but these secrecy systems can be decoded only by a receiving station having the key to the original alterations. There are several methods of scrambling or altering speech transmissions so they will be unintelligible to the ordinary receiver. One method is to produce the usual amplitude **modulation** on some frequency other than that of the final **carrier**. All but one **sideband** of this modulation is discarded and this sideband is then modulated upon the desired carrier in such a manner as to invert the frequencies, i.e., the low frequencies now appear as highs and vice versa. Another method is to divide the audio band into narrow bands by using **filters** and then interchange them, or invert each band separately. Other modifications involve varying time delays for the various bands.

SECURITY. Methods and means for preserving secrecy.

SEEKER. A homing device designed to receive some physical emanation associated with a target and thus direct a missile toward it. (See **homing guidance**.) The most common seeker is the infrared sensitive type.

SEGMENT. In commutated telemetry channels, one of the discrete intervals pertaining to one **bit** of information. (See also **commutation** and **telemetering**.)

SEISMOGRAPH. An instrument for recording earth tremors; usually housed for the purpose in a suitable seismological observatory. There are two classes of seismograph, one for recording horizontal and the other for recording vertical components of vibration. A well-equipped observatory has three, a north-south horizontal, an east-west horizontal, and a vertical recorder. The instruments are somewhat complicated, but the principle is that of a heavy mass poised in such a way that a vibration of its support, together with the inertia of the mass, causes a relative motion of mass and support; and this motion, suitably amplified, produces the record. In the older forms the recording was done mechanically by a stylus tracing on a revolving drum; in more modern types an electromagnetic cur-

rent, generated by the motion, operates a **galvanometer** which, by means of a beam of light reflected from its mirror, produces a photographic record of the earth's vibration on a moving film.

SELECTANCE. The reciprocal of the ratio of the **sensitivity** of a receiver tuned to a specified channel to its sensitivity at another channel separated by a specified number of channels from the one to which the receiver is tuned. Unless otherwise specified, selectance should be expressed as voltage or field-strength ratio. Selectance is often expressed as "adjacent-channel attenuation" (ACA) or "second-channel attenuation" (2ACA).

SELECTED AREAS. To determine the form, extent, and general characteristics of the sidereal universe as a whole, knowledge of the **magnitudes**, **spectral types**, and other characteristics of all of the stars would be necessary. To solve completely a problem of such magnitude is obviously impossible, and the process of statistical discussion becomes necessary. In any problem of statistical analysis a sampling of the material under consideration is necessary. For this purpose, Prof. J. C. Kapteyn, a Dutch astronomer, proposed in 1906 a group of 206 "selected areas" distributed all over the sky in accordance with statistical theory, and requested international cooperation in the determination of the characteristics of all stars in these areas. During the past 50 years a large amount of work has been done on these selected areas, and from a statistical discussion of the results most of our information regarding the structure of the sidereal universe has been obtained.

SELECTIVITY. The ability of a receiver or other circuit to receive only signals of one frequency, rejecting all others. It is thus a measure of the ability of a circuit to differentiate between desired and undesired frequencies.

SELECTOR. A circuit selecting only that portion of a waveform having certain characteristics of amplitude, frequency, phase, or time of occurrence.

SELENIUM. Non-metallic element. Symbol Se. Atomic number 34.

SELENOCENTRIC. Relating to the center of the moon; referring to the moon as a center.

SELENOID SATELLITE. An artificial satellite whose orbit is designed to maintain a fixed configurational relationship with the earth and moon.

SELF-BIAS. A bias produced between the cathode and plate of a vacuum tube by the flow of grid current through a resistor. It is most commonly used in transmitting circuits.

SELF-DESTRUCTION. Actuation of destructive agents to destroy a missile in the event of a target miss or other abortion of the particular mission.

SELF-DESTRUCTION EQUIPMENT. An explosive connected in a self-destruction circuit so that it may be exploded by (a) a time-delay mechanism, (b) a radio-command link, (c) an automatic trip mechanism actuated by engine cutoff, loss of a signal, etc.

SELF-EXCITED OSCILLATOR. A vacuum-tube oscillator that operates without external excitation and solely by the direct voltages applied to the electrodes.

SELF-GUIDED. (1) Directed along a course by use of self-contained devices, as by use of a preset mechanisms, a radio set, or a self-reacting device. (2) Directed in response to built-in self-reacting devices only.

SELF-GUIDED MISSILE. A missile that is not remotely controlled but that instead guides itself along its course by self-contained devices, such as preset or homing devices.

SELF-PROPELLED. (1) Of a missile: is propelled by fuel carried by the missile itself, as in the case of a rocket. (2) Of a vehicle: given motion by means of a self-contained motor.

SELSYN (SELF SYNCHRONOUS). A General Electric Company trade name for a synchro.

SEMI-AUTOMATIC GROUND ENVIRONMENT (SAGE). A defense system providing instantaneous information needed for control of missiles and aircraft used to wage air battles. A Massachusetts Institute of Technology Lincoln Laboratory development.

SEMICONDUCTOR. An electrical conductor having a resistivity in the range between those of metals and insulators, in which the

electrical charge-carrier concentration increases with increasing temperature over some temperature range.

SEMI-MONERGOLIC. Having oxygen for combustion or propulsion contained within the fuel. It is ignited or decomposed by passing it over an appropriate catalyst. Hydrogen peroxide is a typical semi-monergole fuel.

SEMI-MONOCOCQUE. A structure in which sheet stringers are used in conjunction to provide a stiff load-carrying cell. The longerons divide the sheet into small panels with correspondingly improved buckling resistance.

SENL. Standard Equipment Nomenclature List.

SENSE ANTENNA. A receiving antenna, used in conjunction with another directional receiving antenna, that distinguishes the direction of the signal.

SENSE INDICATOR. A flight instrument used to determine whether an air vehicle is flying toward or away from a VHF omnidirectional radio range station.

SENSIBLE ATMOSPHERE. That portion of the Earth's atmosphere within which aerodynamic forces exist, i.e., drag, pressure, temperature, etc. (cf. **effective atmosphere**.)

SENSIBLE HORIZON. A plane that passes through the eye of an observer, at right angles to the vertical and parallel to the rational horizon.

SENSITIVITY. In general, susceptibility to external action, as measured by speed of response or degree of responsiveness, as exemplified by sensitivity to light or other radiation, or sensitivity to electric current. Specific usages are: (1) The ratio of output response to a specified change in the measured variable. (2) The least signal input capable of causing an output signal having desired characteristics; thus the sensitivity of a **camera tube** is the signal current developed per unit incident radiation density (i.e., per watt per unit area). Unless otherwise specified the radiation is understood to be that of an unfiltered incandescent source of 2870°K, and its density, which is generally measured in watts per unit area, may then be expressed in **foot-**

candles. (3) The sensitivity of a **receiver** is the signal input necessary for the receiver to produce a standard output. The amount of the output, the audio-frequency used to modulate the input and the degree of **modulation** should be specified. (4) The current sensitivity of a **galvanometer** is the ratio of deflection to galvanometer current. (5) The sensitivity (or sensitiveness) of a **balance** is the smallest mass to which it can respond. (6) The sensitivity (or sensitiveness) of an **analytical method** is the minimum quantity of a substance which can be detected. (7) The sensitivity of a **voltmeter** is the ratio of its resistance to its full-scale reading, i.e., the inverse of the moment necessary to produce full scale deflection.

SENTRY (WS-117-L). A U.S. reconnaissance satellite, carrying a television-type scanner, powered by a **SNAP** generator.

SEPARATION. (1) The phenomenon in which the boundary layer of the flow over a body placed in a moving stream of fluid separates from the surface of the body allowing a condition of low energy turbulent air to exist in the region between the body and the smooth flow. (2) In multistage missiles, the action time or place at which a burned-out stage is discarded and the remaining missile continues on its way.

SEPARATION VELOCITY. The velocity at which a space missile or space vehicle is moving when some part or section is separated from it.

SEQUENCER. An electronic device used to provide accurately-timed sequential operations necessary to the launching and/or instrumentation of missiles. It normally consists of a series of terminals, power sources, interconnecting patch boards, time-delay circuits, relays, amplifiers and miscellaneous other equipment capable of monitoring and supervising the sequential operation of functions related to missile **launching** and the preparation for launching.

SERGEANT. A U.S. Army solid-propellant rocket designed by the Jet Propulsion Laboratory. Its motor was designed and made by Thiokol Chemical Corporation. No official details have been released. (See **Missile, guided.**) (See also illustration facing Page 378.)

SERIES 1, 2, 3. The three types of **XSM-68** test vehicles that provide a progressive approach to the operational **SM-68** missile.

SERVICEABILITY. The degree to which a missile or equipment is susceptible to use by armed forces personnel. It involves simplicity of design and consequent absence of superfluous members or components, specification of adequate and reliable elements for trouble-free service life, accessibility of critical components, and use of standard parts where possible. Ease of maintenance, readiness with which adjustments can be made, ease of accurate alignment of parts, ease of handling and loading, and many similar criteria are also included.

SERVICE BAND. A band of frequencies allocated to a given class of radio service.

SERVICE TEST. (1) A test, under simulated or actual conditions, to determine the characteristics, capabilities, and limitations of a given piece of equipment or materiel. (2) A similar test made of a plan, method of doing something, or organization. (3) An operational suitability test, especially when used as an attribute, e.g., service-test guided missile. (4) A test made at any point in the development of a piece of equipment or materiel, with the object of predetermining, if possible, ultimate capability and serviceability; i.e., any test made during the research and development stage, or a test to see if a contractor has complied with specifications, or a test on refined or modified material.

SERVICER. A device used to prepare a missile for launching. It is usually a tower or other structure with working platforms from which maintenance and check-out operations are performed.

SERVO (SERVOMECHANISM). A combination of devices for controlling a source of power in which the output (or some function thereof) is fed back and compared to some reference at the input, the difference of this comparison being an error signal used to effect the desired control. Implicit in the definition is the notion of a follow-up action in which the output is forced to be a preassigned function of the input, regardless of the presence of external influences which might normally act to destroy the desired relationship. Within the designed operating limits of a particular

servomechanism, the input may be varied arbitrarily and the follow up action of the output will still be maintained. This characteristic of a servomechanism is to be contrasted with the operation of a regulator in which the output variable is maintained substantially constant. Both servomechanisms and regulators depend for their operation on **feedback** from the output (controlled variable) with subsequent comparison of the quantity fed back with an input (command variable) to generate an error signal. For a regulator the command is a constant quantity, whereas for the servomechanism it is, in general, an arbitrary function of time. A block diagram depicting the fundamental elements of a servomechanism is shown in Fig. 1.

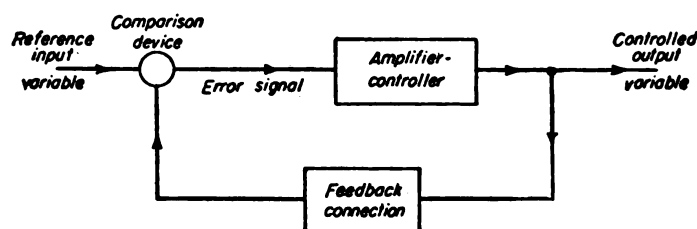


Fig. 1. Block diagram of simple servomechanism.

A typical servomechanism is one which provides control of the motion of an output shaft in response to the motion of an input shaft at a location remote from that of the output shaft. A **synchro** generator is connected to the input shaft, and the voltage output of this device is conveyed by a wire connection to the stator windings of a synchro control transformer located in the immediate vicinity of the output shaft. The rotor of the control transformer is connected to the shaft to be controlled. The difference in angular displacement between the two shafts produces an error voltage in the rotor winding of the control transformer. This error signal is supplied to an amplifier-servomotor combination which effects motion of the output shaft. Whenever the two shafts have the same displacement, there is no error signal. On the other hand, if the input shaft is turned, an error signal is developed and the servomotor turns the output shaft until the two are aligned again and the error signal returns to zero.

Although servomechanisms assume widely different physical forms, analysis usually allows a particular system to be classified as one, or a combination of one or more, of three

basic types. The classifications are based on the relation between the output variable and the error signal which produces it. The different forms of systems are described as Type 0, Type 1, and Type 2, respectively. A Type 0 system is one in which the error signal is proportional to the output variable. If the input and output variables are shaft rotations, a Type 0 control system has a constant error between input and output shafts after position transients have subsided. A constant output in a Type 0 system is accompanied by a constant error signal. In the Type 1 system, on the other hand, the error signal generated is proportional to the derivative of the output quantity and thus a constant error signal accompanies a constant rate of change of the

controlled variable. Referring to the servomechanism in which motion of an output shaft is under the command of motion of an input shaft, a Type 1 servomechanism of this form is capable of having the output shaft follow the input shaft with no error in angular deflection. If the input shaft moves with a constant velocity, however, the velocity of the output shaft will differ by a constant error. In the Type 2 servomechanisms, the error signal is proportional to the second derivative of the output quantity and thus a constant error signal is produced by a constant acceleration of the output member in this type of control system. Corresponding to the relation between the performance of the Type 0 and Type 1 position systems, a Type 2 system is capable of providing both zero position error and zero velocity error between input and output shafts, but the acceleration error must be finite.

In the foregoing account, the assumption has been made that the power to be controlled was continuously applied to the controller element of the servomechanism. A different form of servomechanism is one in which full power is applied to the controlling ele-

ment whenever the error signal exceeds a pre-assigned amount. Such systems are often spoken of as relay servomechanisms. Associated with relay type servomechanisms are the advantages of smaller size, lighter weight, faster response, and in general, reduced system complexity for a given application. On the negative side, however, there is the disadvantage, which prohibits their use in some applications, that the outputs of relay servomechanisms oscillate about the steady state value attainable from the continuous system counterpart. There are many applications, such as guided missile control systems, automatic control systems for aircraft, and certain temperature control situations in which relay systems find ready acceptance, since the hunting type of response is not objectionable enough to offset the advantages of size, weight, and cost.

Another form of servomechanism which is of great importance is the sampled data control system. In this type of system, which is illustrated in Fig. 2 below, the error signal is furnished to the amplifier-controller portion of

in the use of a digital computer in connection with simultaneous operation of several feedback control systems. By use of sampled data techniques the computer may be used periodically to process data from one system, then from the second, and so on until it completes the operating cycle and accepts data from the first system again.

SERVO CONTROL. (1) Control of anything through use of a *servo*. (2) The servo that provides this control.

SERVO CORNER FREQUENCY. The frequency at which the break in the slope of an open loop characteristic curve occurs.

SERVO LINK. A high gain amplifier, usually mechanical, by means of which low power signals are made to operate control surfaces requiring a large power input.

SERVOS, ORDER OF

First—A servo with a zero static error, but a finite steady following error to a step velocity input.

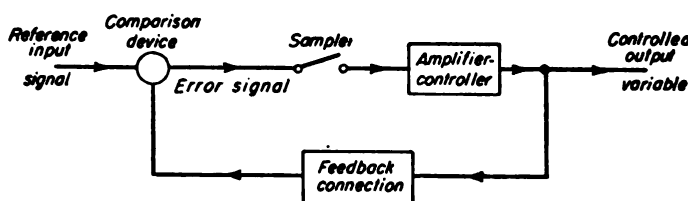


Fig. 2. Block diagram of sampled data control system.

the system at regular intervals of time as the sampler switch is closed for comparatively short sampling intervals. The input to the controller is thus a train of pulses of varying amplitudes, the amplitude of each pulse being equal to the error existing at the sampling instant.

Applications of sample data systems include those situations in which the error information is only available in sample form, as well as those arrangements in which deliberate conversion of continuous data to sampled data is made. A good example of the first situation is had in the data supplied by an automatic tracking radar system which scans in two coordinates and thus can furnish information on a particular target only at the discrete time intervals when the antenna direction permits radio frequency energy to intercept the target. An illustration of the second possibility arises

Second—A servo with a zero steady following error for a step velocity input. It has one time lag in the loop. (Termed zero velocity error servo.)

Third—Similar to a second order servo with two time lags in the loop. (See Fig. 1, Page 554.)

SERVO STABLE. A servo system in which the output is always finite, or limited, for any finite input. Most servos are stable *only* if the open loop transfer function gain is less than unity at any frequency at which the open loop transfer function phase angle is 180 degrees. (See Fig. 2, Page 554.)

SERVO SYSTEM. An error reducing closed-cycle automatic-control system so designed that the output element or output quantity follows as closely as desired the input to the

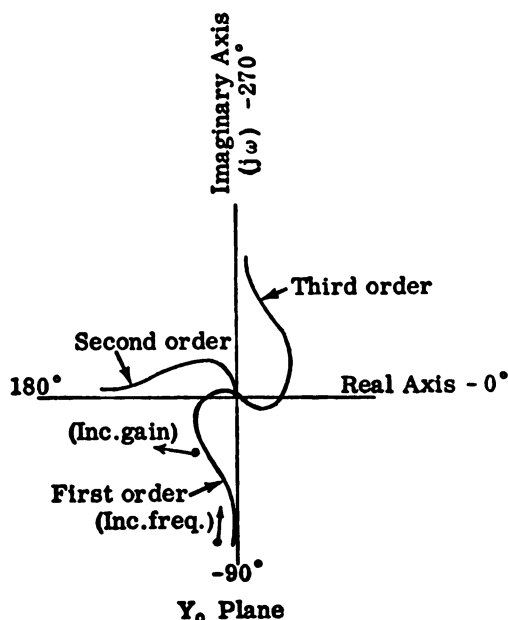


Fig. 1. Generalized Nyquist plots for first, second & third order servos.

system. The output is caused to follow the input by the action of the servo-controller upon the output element in such a way as to cause the instantaneous error, or difference between output and input to approach zero. All servo-systems are dynamic systems containing at least one feed-back loop which provides an input signal proportional to the deviation of the actual output from the desired output; this property distinguishes servo-systems from ordinary automatic-control systems.

In general, servo-mechanisms exhibit the following properties:

- Include power amplification.
- Are "error sensitive" in operation.
- Are capable of following rapid variations of input.

(See Fig. 3.)

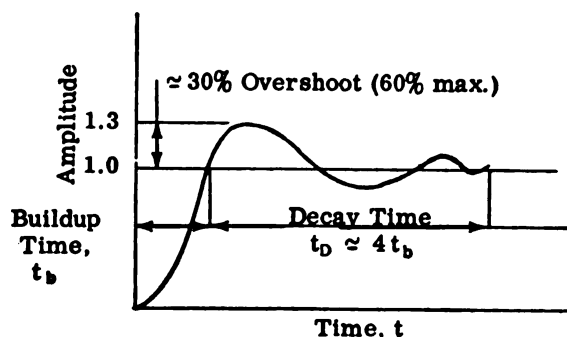


Fig. 2. Characteristics of a typical stable servo.

$$c = \frac{F}{2\sqrt{KJ}}$$

$$s^2 + 2c\omega_0 s + \omega_0^2 = 0$$

$$c > 1 \quad \begin{aligned} r_1 &= -\omega_0 c + \omega_0 \sqrt{c^2 - 1} \\ r_2 &= -\omega_0 c - \omega_0 \sqrt{c^2 - 1} \end{aligned}$$

$$c < 1 \quad \begin{aligned} r_1 &= -\omega_0 c + j\omega_0 \sqrt{1 - c^2} \\ r_2 &= -\omega_0 c - j\omega_0 \sqrt{1 - c^2} \end{aligned}$$

$$c = 1 \quad \begin{aligned} r_1 &= -\omega_0 c \\ r_2 &= -\omega_0 c \end{aligned}$$

where c = relative damping factor
 F = viscous friction coefficient
 K = gain
 J = load inertia

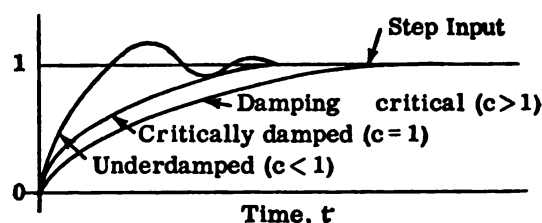


Fig. 3. Servo system generalized response to a step input.

Some *servo systems* have variable amplification features built into them. For example, during the early period of flight of a slowly accelerating missile, control surfaces would have to displace through greater distances to effect flight control than these same surfaces would at high speeds. Also, the force necessary to move these surfaces at high speeds would be greater (assuming flight in the atmosphere). Therefore, various gain factors might be necessary and these would be introduced according to the flight program. *Servo systems* can be electric, pneumatic, hydraulic, mechanical, or combinations of these. They may be either continuous or discontinuous depending upon whether their control is applied smoothly or in "bangs." Also, the following terminology is frequently used in connection with servo systems: *Open loop (cycle) control*, where the control operation is independent of the result, e.g., the automatic washing machine where there is no evaluation of results and the cycle is always the same. *Closed loop (cycle) control*, where the control operation is a function of the result, e.g., the heating system with thermostatic control. *Discontinuous control*, in which the flow of energy is zero or some other predetermined value such as "on" or "off," e.g., the lighting system switch. *Continuous control*, in which the flow of energy may vary between zero and

some maximum value. The *closed-loop continuous control* system is usually used with missiles. In general it uses the feedback principle that distinguishes servo systems from other automatic control systems. A servo system need not be entirely mechanical. A human operator is often used as part of the link (i.e., a "biomechanical link").

SERVO SYSTEM ANALYSIS. A scheme for mathematical investigation of servos using differential equations, in which the mechanical response is determined from the assumption that the error of the system is equal to the difference between the input and output errors. Various common cases of analysis are:

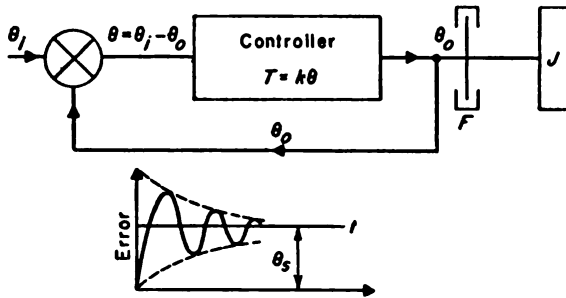


Fig. 1. Servo—viscous-damped.

Viscous damped servo. (See Fig. 1.) In this case, T is the torque of the system, J is the moment of inertia of the load, θ = the error angle, and α is the acceleration of the output due to T . Thus:

$$T = J\alpha$$

$$K\theta - F\frac{d\theta_o}{dt} = T = J\frac{d^2\theta_o}{dt^2}$$

Letting $p\theta_o = \frac{d\theta_o}{dt}$, and $p^2\theta_o = \frac{d^2\theta_o}{dt^2}$

Then: $K\theta = Jp^2\theta_o + Fp\theta_o$,

and since $\theta = \theta_i - \theta_o$ or $\theta_o = \theta_i - \theta$

Therefore: $K\theta = Jp^2(\theta_i - \theta) + Fp(\theta_i - \theta)$

and: $Jp^2\theta + Fp\theta + K\theta = Jp^2\theta_i + Fp\theta_i$.

Error rate damped servo. (See Fig. 2.) Here:

$$T = K\theta + Lp\theta = Jp^2\theta_o$$

or $Jp^2\theta + Lp\theta + K\theta = Jp^2\theta_o$

Combined damped servo. (See Fig. 3.) Here:

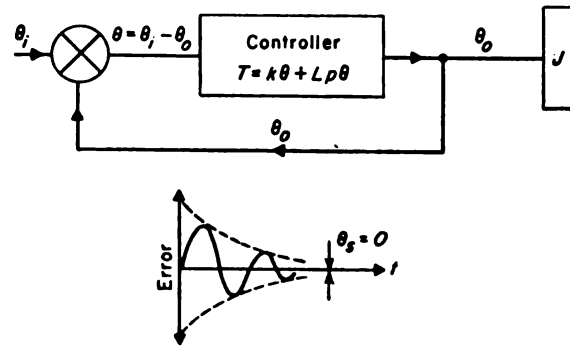


Fig. 2. Servo—error rate damped.

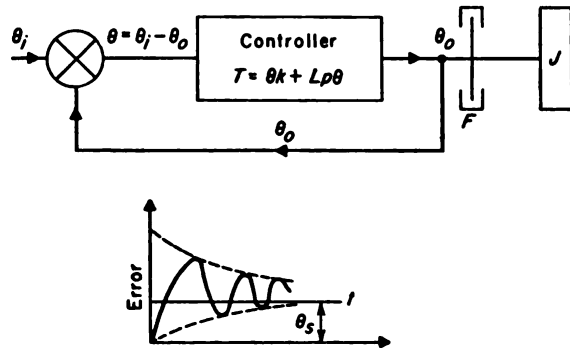


Fig. 3. Servo—combined damped.

$$T = K\theta + Lp\theta - Fp\theta_o = Jp^2\theta_o$$

and $Jp^2\theta + (L + F)p\theta + K\theta = Jp^2\theta_i + Fp\theta_i$.

Combined damped with integral control. (See Fig. 4.) Here:

$$T = K\theta + Lp\theta + Np^{-1}\theta$$

and

$$Jp^2\theta + (L + F)p^2\theta + Kp\theta + N\theta = Jp^2\theta_i + Fp^2\theta_i$$

The above equations are used to determine the capabilities and merits of a particular system. The technique makes use of the solution of the differential equations indicated

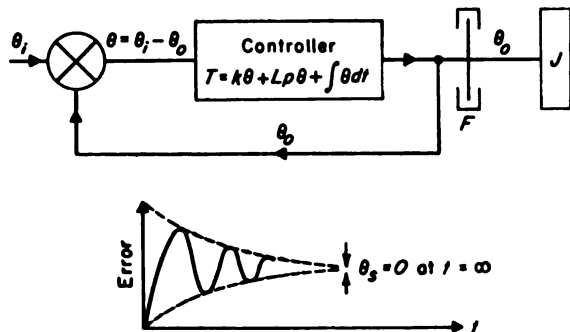


Fig. 4. Servo—combined damped with integral control.

to determine the response of the system under different inputs. The analysis begins from the fact that only two types of forces can operate on the system: accelerating and decelerating. Accelerating forces would be the input torque or any amplifications. Decelerating forces would be inertia, friction and damping. An equation is formed by adding or subtracting the accelerating and decelerating forces. When the equation is set up, various types of inputs (e.g., step position, constant velocity, sinusoidal or other) are introduced and followed through the equations mathematically to determine their effect on the stability and response of the system.

SERVO TABLE. A precision test table, servo-driven at a rate to eliminate the effect of the earth's rotation when properly aligned and used to evaluate drift rates of gyroscopes.

SERVO, UNSTABLE. A servo in which the output drifts away from the input without limit.

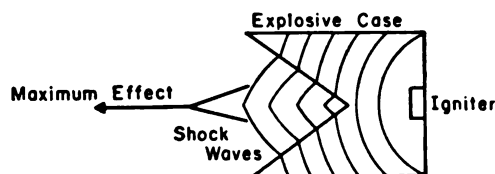
SERVO, VELOCITY LIMITING. A servomechanism in which the performance is limited by the velocity (or rate) attainable by the servo.

SERVOMECHANISM. Servo.

SERVOMOTOR. A motor that supplies power for moving a servo or a component of a servo.

SEXTANT. (1) Any of several similar instruments for measuring angles, as of a celestial body. (2) Such an instrument with an arc graduated for one-sixth of a circle.

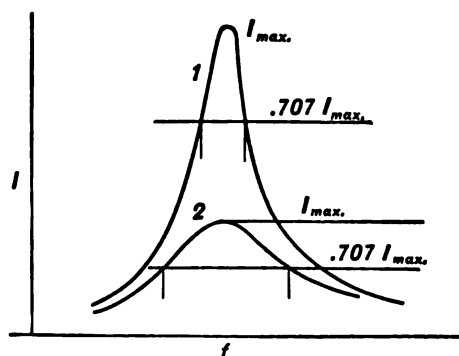
SHAPED CHARGE. A type of warhead based on the Munroe effect, which focuses explosive forces into very sharp beams of high gain. Thus, a conical shaped cut-out in an explosive charge has the property of reinforcing the shock waves resulting from the explosion along the axis of the cone. If the wide end of the cone is placed against some



Action of shaped charge.

object to be destroyed, the shaped charge blasts into it with a force several times greater than is obtainable from the charge itself. The shaping tends to focus the shock energy, and thereby obtain a concentrated effect along a narrow line. It is especially useful for the penetration of armor, as of a tank.

SHARPNESS OF RESONANCE. Since resonant circuits give a response which varies with frequency, reaching a maximum at the resonance frequency and dropping on either side, it is convenient to have some means of comparing different circuits. The usual purpose of such circuits is to select certain frequencies in preference to others so the common method of defining the sharpness of resonance is to specify the frequency band in which the response will exceed an arbitrary value. This arbitrary value is often taken as 70.7% of the maximum as this is the point where the power is half the value at resonance. The narrower the frequency band between these two points the sharper the resonance, thus in the figure the circuit having the response curve 1 has much sharper resonance than that of curve 2. The frequency difference between these two half-power points is approximately equal to the resonance frequency divided by Q ($Q > 10$).



SHEAR. (1) In mechanics, the action or stress causing or tending to cause two contiguous parts to slide on each other parallel to their plane of contact. Rivets are subject to shear. Bolts are normally designed to withstand both shear and tension. (2) In meteorology, wind shears are upper air conditions in which there is a high difference in velocity between two layers of winds at nearly the same altitude.

SHEAR LAG. In box and wide flange beams, the difference in shear from that predicted by

elementary theory. Flange bending stresses on a wide flange beam may not be constant along a line parallel to the neutral axis. The shear stresses, which are related to the bending stresses will not correspond to those predicted by elementary theory—this is the shear lag.

SHEET STIFFENER. In airframe construction, the combination of thin cover or surface plates or skin reinforced by longitudinal stiffeners.

SHIELD. Any material used to reduce the amount of radiation reaching one region of space from another region of space.

SHIELDED PAIR. A two-wire electrical transmission line surrounded by a metallic sheath.

SHOCK. A suddenly applied force or a sudden change in direction of a motion or a sudden change in velocity of a motion. A shock can be specified in terms of the envelope of spectra for measured shocks (assuming no narrow frequency bands).

SHOCK, DETACHED. In supersonic aerodynamics, the flow condition occurring when the shock wave created at the leading edge of a body is not attached to the body but has moved ahead. The shock wave will acquire a smooth, rounded configuration in the immediate vicinity of the leading edge. Condition occurs if the wedge or cone angle exceeds a certain value for a given Mach number; or for any blunt body in a supersonic stream. The flow immediately behind a detached shock is subsonic.

SHOCK EXCITATION. Excitation, shock.

SHOCK EXCITED PEAKER. An electronic system employing a **tank circuit** at the plate of a vacuum tube to accept a square wave and put out a single positive pulse. It is essentially the same circuit as a ringing oscillator, but the tank circuit is between B+ and the plate, which gives a peaking effect through **critical damping**. When the tank circuit is between the cathode and ground, the circuit becomes a ringing oscillator and there is no critical damping.

SHOCK FRONT (PRESSURE FRONT). In supersonic aerodynamics, the initial part

of the shock wave in which the pressure rises from zero up to its peak value. The shock front is generally assumed to be infinitely thin and a mathematical discontinuity, but is actually of finite thickness. This front is not in equilibrium; it is a transition region between equilibrium conditions in the air ahead of the shock and the changed gas mixture behind it.

SHOCK, GROUND. Ground shock.

SHOCK LAYER. In supersonic aerodynamics, the region between the shock front and the boundary layer; assumed to be an inviscid flow. Radiation from the shock layer to the nose cone of high speed missiles is one of the causes of skin heating.

SHOCK LAYER COMPOSITION. The composition of air is changed by its passage through the shock and into the shock layer where it reaches some sort of thermodynamic equilibrium. Instead of the familiar mixture of about four-fifths nitrogen, one-fifth oxygen and traces of rare gases, the air in the shock layer of a Mach 20 missile is about half atomic nitrogen, one-quarter molecular nitrogen and one-quarter atomic oxygen. Nitric oxide will also be present to some extent.

SHOCK, LOCAL. A suddenly applied force on an object which does not produce significant displacement except immediately adjacent to the point of application of the force.

SHOCK MOTION. A sudden transient motion with significant relative displacement. In packaging, a sudden change in the velocity of an object, e.g., from rest to motion or vice versa, a condition also termed **velocity shock**.

SHOCK, NORMAL. In aerodynamics, a **shock wave** generated by a flow compression which is perpendicular to the direction of supersonic flow. (See illustration in entry for **diffuser**.)

SHOCK, OBLIQUE. In supersonic aerodynamics, the flow condition occurring when air (or gas) flow is forced to turn in such a direction as to interfere with the flow of air in adjacent stream layers. (See illustration in entry for **diffuser**.)

SHOCK PULSE. The complete description of a shock, i.e., either the force-time relation-

ship of the shock or the displacement-time relationship of the object.

SHOCK SPECTRUM. A measure of what a shock does to a complex elastic device. The value at any frequency, f , of the shock spectrum is the maximum acceleration which is experienced by a mass supported by an essentially undamped spring with linear elasticity whose natural frequency is f and which is excited by the shock motion. Velocity or displacement may be used in place of acceleration. Shock spectra may also be specified with stated amounts of damping.

SHOCK STALL. A sudden reduction of lift on an airfoil brought about at supersonic speeds by airflow separation aft of a shock wave. (See **compressibility stall**.)

SHOCK, SWALLOWED. The condition in a supersonic **diffuser** when the shock wave has moved inside the intake lip. This is usually an *off-design* condition. The diffuser or internal drag is increased.

SHOCK TEST. An environmental test intended to subject the test article to a sharp-edged input representative of design requirements. Characteristics of the test may be varied, depending on the wave shape desired.

SHOCK TUBE. A relatively long tube or pipe in which very brief high-speed gas flows of high enthalpy are made to occur by the sudden release of gas at a very high pressure into the low-pressure portion of the tube, the high-speed flow as it moves into the region of low pressure being preceded by a shock wave. The shock tube is used as a tool in the study of gases or as a kind of intermittent wind tunnel.

SHOCK TUNNEL. An intermittent blow-down type of **wind tunnel** with the driving medium being the high-pressure, high-temperature gas pocket produced in the shock tube. By expanding the hot gas pocket through a supersonic nozzle it is possible to extend the useful range of a shock tube to a more accurate simulation of hypersonic flight.

SHOCK, VELOCITY. **Velocity shock.**

SHOCK WAVE. A surface or sheet of discontinuity (i.e., of abrupt changes in conditions) set up in a supersonic field of flow,

through which the fluid undergoes a finite decrease in velocity accompanied by a marked increase in pressure, density, temperature, and entropy, as occurs, e.g., in a supersonic flow about a body. These changes are irreversible owing to some of the pressure energy being lost to heat. Shock waves are commonly called compressive waves, and may be either normal or oblique to the gas-stream direction. The stream upon passing through a normal shock always has its velocity reduced from supersonic to subsonic. In passing through an oblique shock, the velocity is reduced but is still supersonic. In the case of shock waves ahead of blunt bodies of revolution, wherein a normal shock blends into an oblique shock pattern, there will be a sonic line dividing the flow behind the shock wave into regions of subsonic and supersonic flow. In such cases the total stagnation pressure is reduced, while the density, static pressure, and free-stream temperature are increased in the gas stream. An approximation of the thickness of a shock wave is given by:

$$t = \frac{1}{v_1 - v_2}$$

where t is the thickness, and v is the velocity (before and after) in centimeters per second. In supersonic flight, the presence of a shock wave may increase drag as much as ten times the value before formation of the wave. The pattern of a shock wave depends upon the shape of the body, the boundary layer effects experienced by flow over it, the **Mach number** and the **Reynolds number** of the body.

Shock waves commonly arise (1) in the motion of an air vehicle or missile at transonic or supersonic speed, or (2) in the expansion of gases away from an explosion.

SHOCK WAVE PHOTOGRAPHY. In aerodynamic research, a model of the newly designed airframe is tested in a wind tunnel. The formation of shock waves on this model is investigated and normally photographed. There are four common methods for this photography: (1) direct-shadow (oldest method used for bullet shock waves), (2) **Schlieren method** (knife-edge at optical focus), (3) lens, and (4) mirror. These give only qualitative information about shocks, however: if quantitative information is desired the **interferometer** or **Ronchi techniques** are used. All photography depends upon the

utilization of the changes in refractive indices of the fluid through which the body is traveling. The *direct-shadow divergent-light method* (or *Dvorak direct shadow method*) uses divergent light and is a method used since the late 19th century for the photography of bullet shock waves. It is sometimes called *spark photography*. It cannot be used where glass must be between the object and the camera. The *direct shadow parallel-light method* is used for large amplitude shock waves. The Schlieren method is best for faint shock waves, Prandtl-Meyer expansions and other gradual density gradients. Other lesser-used methods include: smoke or water condensation, which is good for direct visualization of intense shock waves and complicated three-dimensional effects; ultraviolet and X-ray absorption techniques in which the denser air absorbs more radiation; and the interferometer technique which gives point-to-point survey of the air-density field—good but expensive in time and money.

SHOOT. The complete action of preparing a rocket for launching from the earth's surface and of firing it off, as, to attend a shoot.

SHORAN. (*SHort RAnge Navigation*). A precision position-fixing system using a pulse transmitter and receiver and two transponder beacons at fixed points. (See *navigation, hyperbolic*.)

SHORT-CIRCUIT. An electrical circuit is considered to be shorted when the terminals are connected directly together with only the **impedance** of the short connecting leads between them, thus for all practical purposes there is no **resistance** between them, hence no voltage can exist between them. While shorting a circuit which does not contain and is not connected to any source of voltage will produce no harmful effects, shorting a set of terminals across which a voltage normally exists will produce in many instances disastrous current flows.

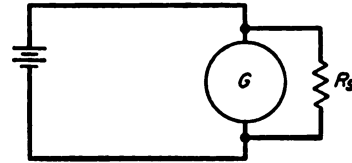
SHOT. (1) An act or instance of firing a rocket, especially from the earth's surface, as, the shot carried the rocket 200 miles. (Cf. *shoot*.) (2) The flight of a rocket, as, the rocket made a 200-mile shot; the action of a rocket engine firing.

SHOT EFFECT. The noise produced by the random emission of electrons from a vacuum

tube cathode. It is considerably reduced or "smoothed" by space charge effects.

SHOT NOISE. Shot effect.

SHUNT. An electrical bypath so arranged that an **electric current** divides and flows partially through the shunt, and partially through the equipment that is shunted. Shunts are used extensively to reduce the sensitivity and to lower the effective resistance of **galvanometers**. (See figure.)



Shunt resistance.

SHUNT EXCITED. This is a method of exciting tower **antennae** which are not insulated from the **ground** at the base. The feeder is connected to a point about $\frac{1}{3}$ of the way up the antenna, the exact location depending on many factors and usually involving some cut-and-try. For proper operation the feeder should slope up to the point of attachment from a point some distance from the base of the antenna, the slope being adjusted experimentally. The term is also applied to the method employed in providing field current for d-c **dynamos**. A shunt-excited machine is one in which the field windings are connected across the **armature** terminals.

SHUNT FED. Shunt excited.

SHUT OFF. In rocket propulsion, a term proposed by some authorities (notably the Jet Propulsion Laboratory) for the intentional termination of burning of a rocket according to a predetermined plan. The term is intended to distinguish from **cut-off** which is thought to imply command cut-off for safety reasons. Shut-off is not a universally accepted distinction. Cut-off is generally preferred for use since there are actually more than the two simple cases of cut-off and shut-off. The accepted practice is to identify the kind of cut-off, e.g., emergency cut-off, normal cut-off, timer cut-off, pressure switch cut-off, etc.

Si. Silicon.

SI. Shipping Instructions. (Sometimes ASI—Amended Shipping Instructions.)

SIDEBAND(S). (1) The frequency bands on both sides of a carrier frequency within which fall the frequencies of the wave produced by the process of modulation. (2) The frequency components lying within such bands. In the process of amplitude modulation with a sine-wave carrier, the upper sideband includes the sum (carrier plus modulating) frequencies; the lower sideband includes the difference (carrier minus modulating) frequencies. When only one of these is employed the modulation is said to be single sideband.

SIDE LOBE. A portion of the radiation from a (radar) antenna outside the main beam, and usually of substantially smaller intensity. A side lobe is a region between two minima in the pattern.

SIDEREAL DAY. A day as measured by sidereal time. A sidereal day begins and ends when the first point of Aries is directly over the reference meridian. Because of the motion of the earth around the sun, a sidereal day is almost 4 minutes shorter than the solar day.

SIDEREAL HOUR ANGLE. The angular distance between an hour circle passing through the first point of Aries to the hour circle passing through a given celestial body, measured westward from 0 through 360 degrees.

SIDEREAL TABLE. A test device with a servo-driven table which is used to cancel out earth's rotation. The axis of the table is aligned for the particular latitude of location. Single degree of freedom gyroscope tests are made by connecting the gyroscope sensitive axis to the table servo. At the end of 24 hours, any difference in position from the start is a measure of the gyroscope drift rate, etc.

SIDEREAL TIME. Time measured by the rotation of the earth with respect to the stars. It is the arc measured from Greenwich meridian westward along the equator to the vernal equinox.

SIDEWINDER. A U.S. Navy rocket, of the air-to-air type, which became operational in 1956. It is also programmed for U.S. Air

Force use on F-100D, F-100F, F-100A, and F-105; ADC. It is powered by a solid-propellant rocket. Philco and General Electric are among prime contractors. It uses infrared heat-seeking guidance. It weighs 155 pounds; it is 9 ft. 4 in. long; and it has a ceiling over 50,000 ft. (See *missile, guided*.) (See also illustration facing Page 379.)

SIGNAL. (1) An independent input variable. (2) A visual, audible, or other detectable physical quantity used to convey information. (3) The intelligence, message, or effect to be conveyed over a communication system. (4) A signal wave.

SIGNAL, BLANKING. Blanking signal.

SIGNAL CONDITIONER. In instrumentation, a device used to shape or adapt a signal to the requirements of the data transmission link.

SIGNAL GENERATOR. A test instrument that generates an unmodulated or tone-modulated radio-frequency signal at any frequency needed for aligning or servicing electronic equipment. Also termed an all-wave signal generator, oscillator, or test oscillator.

SIGNAL, INPUT. The power fed into the input of a device or circuit.

SIGNAL LEVEL. At any point in a transmission system, the difference of the measure of the signal at that point from the measure of an arbitrarily-specified signal chosen as a reference. In audio techniques, the measures of the signal are often expressed in decibels, thus their difference is conveniently expressed as a ratio.

SIGNAL, OUTPUT. The power delivered by a device or circuit.

SIGNAL STRENGTH. A measure of the power output of a radio transmitter at a particular location. It is usually expressed as millivolts per meter of effective height of the receiving antenna employed.

SIGNAL-TO-NOISE (S/N) RATIO. In an electrical system or device for conveying intelligence, the ratio of the value of the signal to that of the noise. This ratio is usually in terms of peak values in the case of impulse noise (see *noise, impulse*) and in terms of the root-mean-square values in the case of the

random noise (see **noise, random**.) Where there is a possibility of ambiguity, suitable definitions of the signal and noise should be associated with the term; as, for example: peak-signal to peak-noise ratio; root-mean-square signal to root-mean-square noise ratio; peak-to-peak signal to peak-to-peak noise ratio, etc. This ratio is often expressed in decibels. This ratio may be a function of the bandwidth of the transmission system. The term is sometimes used analogously in servomechanisms.

SILICON. Metallic element. Symbol Si. Atomic number 14.

SILVER. Metallic element. Symbol Ag. Atomic number 47.

SILVER THAW. After a period of cold weather and below-freezing temperature a mass of warm air passing over the region causes frost or glaze to form on objects that are still at a low temperature. This condition is known as a silver thaw, and usually lasts only a few hours, as the warm air soon warms all exposed objects above 32°F.

SIMPLE HARMONIC MOTION. Motion in which the particle is attracted towards an origin by a force directly proportional to the instantaneous distance of the particle from the origin. The resulting periodic motion is characterized by a space-time graph of simple sine form.

The differential equation of motion is

$$m \frac{d^2x}{dt^2} = -kx$$

where m is the mass of the particle, k is the

constant of proportionality, x is the displacement from origin.

The solution of the differential equation yields the displacement as a function of the time.

$$x = A \frac{\sin}{\cos} \{2\pi ft + \epsilon\}$$

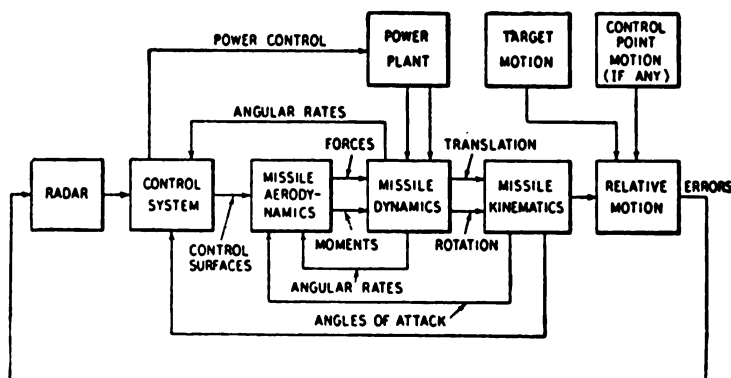
where A is the amplitude of motion, f is the frequency $= (1/2\pi) \sqrt{k/m}$, ϵ is the epoch determined by the value of the function at $t = 0$.

The projection of a particle moving in a circle of radius A and with frequency f onto any straight line in the plane of the circle travels according to the above sinusoidal formula. This is called the circle of reference.

SIMPLEX. A method of operation which permits performing two independent functions alternately as an effective means of simultaneous operation: e.g., alternate firing from several launchers with the same guidance radar. Contrast with **duplex**.

SIMULATION. A technique for studying an operation, such as that of a guided missile by its simulation in the laboratory. Both physical environment and dynamic behavior can be simulated to varying degrees. Simulation is the imitation of the behavior of the actual missile system by the behavior of some other device. This other device can be made more flexible than the final "hardware"; changes in it can be accomplished with relative ease and at low cost and it can be subjected to performance tests under controlled conditions. In its most basic form this simulator may simply set up the equations governing the behavior of the guided missile. (See figure.)

SIMULATOR. (1) A device which solves a problem by use of components which obey the



Block diagram depicting simulation of a missile guidance system.

same equations as the system being studied. Frequently, an electrical analogue or rotation instead of translation is used for mechanical problems. In general, a simulator is an alternative means of determining the effects of changing each of several design parameters at much less expense than building and testing complete missiles or systems. A simulator which operates only in the yaw (pitch) plane is termed a **yaw** (or **pitch**) simulator. The missile is assumed to be completely roll-stabilized and the problem is solved in a single plane. (2) A **training device** which simulates all or part of a missile's operations during preflight checkout and flight.

SINGLE-BASE PROPELLANT. Propellant, single-base.

SINGLE DEGREE OF FREEDOM (FREE) GYROSCOPE. Gyroscope, single degree of freedom.

SINGLE HOP. A term referring to the relatively long range spanned by a radio wave departing from its transmitter at a small angle to the horizontal. This type of wave penetrates only a relatively short distance into the ionosphere before it is reflected to the earth's surface.

There is a definite maximum range that can be spanned by "single hop" transmission. This is the distance covered by a ray departing horizontally. It is about 1500 miles in the case of E-layer transmissions.

SINGLE SAMPLING. Sampling inspection in which a decision to accept or to reject is reached after the inspection of a single sample.

SINGLE SHOT HIT PROBABILITY (SSHP). In gunnery, the probability that a single round will hit the target. Since no event is 100% possible, all SSHP's are less than unity. (See **kill probability**.)

SINGLE-SIDEBAND TRANSMITTER. Transmitter, single-sideband.

SINGLE-STAGE MISSILE. A rocket missile with a single charge, as without a **booster**. (See **rocket, multistage**.)

SINS. An abbreviation for Ship's Inertial Navigation System. It was developed by the U.S. Navy for use on **Polaris** submarines. It makes use of a gyro-stabilized platform

similar to an inertial guidance system for a missile.

SIRIUS. Sirius (α **Canis Major**) is the brightest star in the sky and volumes have been written concerning its matchless brilliancy. Astronomically, Sirius is particularly interesting as being the typical, A, **spectral type**. The companion of Sirius is the first **white dwarf** discovered.

SKEWED. Not square or regular in shape. A skewed distribution has a preponderance of values occurring in one direction. Positively-skewed means preponderately in the conventional positive direction of the Cartesian coordinate system, and negative-skewing means chiefly in the negative direction.

SKID STRIP. (1) A longitudinal strip on the fuselage of a pilotless aircraft upon which it can be launched and/or landed. (2) A landing strip on which missiles are recovered.

SKIN DEPTH. In an electrical conductor, the depth below the surface at which the current density has decreased one **neper** below the surface current density. (See **skin effect**.)

SKIN EFFECT. The phenomenon wherein the depth of penetration of electric currents into a conductor decreases as the frequency of the current is increased. At very high frequencies the current flow is restricted to an extremely-thin, outer layer of the conductor. In this layer it presents essentially a "current sheet," which shields parts of the conductor away from the conducting surface, from the effects of external fields to the extent that there is little or no tendency for current to flow in those regions.

SKIN FRICTION. Drag.

SKIN TEMPERATURE. The outer-surface temperature of a body.

SKIP DISTANCE. (1) The distance between two successive reflections of a radio wave from the ionosphere. (2) The width of the **skip zone**.

SKIP ZONE. The area within the range of a radio transmitting station in which that station's signals are heard poorly or not at all—affected area determined by operating frequency of station and height of ionized layers in ionosphere.

SKY CONDITION. The state of the cloud cover in the sky. In terms of tenths of sky covered, airways' observers in the United States recognize four sky conditions:

- (a) Clear sky is less than $\frac{1}{10}$ cover of clouds.
- (b) Scattered clouds is $\frac{1}{10}$ to $\frac{5}{10}$ cover.
- (c) Broken clouds is more than $\frac{5}{10}$ but not more than $\frac{9}{10}$ cover.
- (d) Overcast is more than $\frac{9}{10}$ cover.

International practice and observations made for synoptic charts in North America recognize 10 states of the sky. They are indicated by code numbers as follows:

- 0...No clouds
- 1...Less than $\frac{1}{10}$
- 2... $\frac{1}{10}$
- 3... $\frac{2}{10}$ to $\frac{3}{10}$
- 4... $\frac{4}{10}$ to $\frac{5}{10}$
- 5... $\frac{7}{10}$ to $\frac{8}{10}$
- 6... $\frac{9}{10}$
- 7...More than $\frac{9}{10}$ but with openings
- 8... $\frac{10}{10}$
- 9...Sky obscured by fog, dust, etc.

SKY SCREEN. On guided missile proving grounds, a type of flight safety device consisting of some means for observing a missile and comparing its flight path with a standard acceptable flight path. Sky screens are *wire* frames for sighting, *optical* telescopes with grid reticles, or *electronic* tracking devices. A pair of sky screens oriented at 90° are used to provide elevation and azimuth limits. Range limit is about 2000 ft.

SKY SYMBOLS. Symbols used to indicate cloud conditions. The four basic cloud symbols are:

○—Clear	Sky clear of clouds or less than $\frac{1}{10}$ th obscured
⊙—Scattered Clouds	$\frac{1}{10}$ th to $\frac{5}{10}$ ths obscured
⊕—Broken clouds	More than $\frac{5}{10}$ ths but less than $\frac{9}{10}$ ths obscured
⊗—Overcast	More than $\frac{9}{10}$ ths of sky covered

NOTE: A slant (/) following cloud symbol indicates high clouds.

A plus sign (+) preceding a symbol indicates dark clouds.

A minus sign (−) preceding a symbol indicates thin clouds.

SKY WAVE. A radio signal which reaches a given receiver after being reflected from the **ionosphere** rather than traveling over the surface of the earth.

SKYHOOK. The name of the large plastic balloons used for high altitude research by the U.S. Navy.

SKYLARK. A British upper air rocket designed for the International Geophysical Year. It was a solid propellant type intended to reach 100 miles altitude. It was unguided, approximately 25 feet in length, 18 inches in diameter and capable of carrying 65 pounds of payload. It was designed to use the **Raven** solid propellant motor. The rocket was scheduled for firing at Woomera, Australia, late in 1956.

SKYROCKET. (1) A fireworks rocket that is fired into the sky, there sometimes to explode in a burst of fireballs. It is commonly made with a heavy paper combustion chamber and a long stabilizing stick. (2) The name of a high speed research rocket aircraft made by Douglas Aircraft Company in cooperation with the National Advisory Committee for Aeronautics. In its first form the Skyrocket was powered with both a jet engine and a rocket motor. The jet engine allowed normal takeoff and landing. The jet engine was a J-34 turbojet by Westinghouse and the rocket motor was made by Reaction Motors Incorporated, the same type as used in the Bell X-1. The rocket motor consisted of four separate combustion chambers developing a thrust of 1500 pounds each, burning LOX and alcohol with a hydrogen peroxide steam pump feed. The overall weight of the Skyrocket was approximately 15,000 pounds. Wing span was 25 feet and length 45 feet. The first flight was in 1948. In 1950 tests were made using an air-launching technique from a specially modified B-29 at an altitude of 35,000 feet. The Skyrocket flew to 70,000 or 80,000 feet with its rocket motor and then entered a shallow dive with full power on. Speeds exceeding Mach 2.0 were attained. Maximum altitude attained was 83,235 feet. The pilot wore a full pressure suit. During the test all fuel was expended and the plane landed as a glider.

Tests took place at Edwards Air Force Base (Muroc Dry Lake), California. Three Sky-rockets were made and were followed by the Douglas X-3. In August, 1953, Lt. Col. Marion E. Carl, USMC, flew the D-558-2 to 83,235 feet. On 20 November, 1953, the D-558-2 piloted by Scott Crossfield attained 1327 miles per hour. In the summer of 1954, Major Arthur Murray, USAF, flew the Sky-rocket at approximately this same speed and altitude.

SLANT RANGE. Range, slant.

SLAVE STATION. Slave unit.

SLAVE UNIT OR EQUIPMENT. Equipment which is subordinate to some other piece of equipment, e.g., a station taking its command to function from the other or "master" station. In essence the term "slaving" means synchronized to follow the command of some programming station. For an example of slaving technique, see **Loran**.

SLAVED GYRO. A gyro that is controlled by a magnetic force through a transmitter, as in a **gyrosyn**.

SLAVED GYRO MAGNETIC COMPASS. A compass, such as the **gyrosyn**, in which the gyro is controlled by a magnetic force.

SLENDERNESS RATIO. Ratio of the length to diameter of a missile used in connection with aerodynamic studies. Sometimes termed fineness ratio.

SLEW. An artillery term meaning to move rapidly on a pivot. In ordnance it refers to the more rapid than normal shifting of the direction of fire from one sector to another without using the normal hand cranks but disengaging them and turning the whole piece bodily. On military equipment special clutches and releases are provided for slewing. In electromechanical equipment normal tracking rates may be too slow to enable rapid engagement of targets. Special arrangements are often made to give extra-rapid motion in one or more of the degrees of freedom. Slewing rates have an important bearing on the field efficiency of military equipment. They will be measured in degrees per second, radians per second, or mils per second in angular situations. The term slewing is also used in connection with radar

sets. Slewing the antenna means to disengage it from its normal drives in order to move it rapidly to another desired orientation. Slewing is also applied to the ranging capability of a radar. One speaks of slewing in or out in the range direction. This is strictly an electrical manipulation of the ranging circuits (although there may be a mechanical movement of the ranging indicators). This is rapid searching with the ranging circuits to get the radar "on" in range.

SLIP FLOW. In supersonic aerodynamics, flow wherein the mean free path of the air molecules is of the same order of magnitude as the thickness of the boundary layer. Under these conditions the air in contact with the body's surface is no longer at rest with respect to that surface.

SLIPSTREAM. The current of air driven over an air vehicle by virtue of its motion through the air. The slipstream has a velocity slightly greater than the airspeed (in order to "get around" the vehicle).

SLIVER LOSS. The portion of a solid propellant rocket charge which is inadvertently unburned. Slivers result from the convergence of the burning surfaces toward a common point and either are discharged with the exhaust gases or left in the rocket case. (Slivers typically represent 3 to 4% of the propellant charge.)

SLOE. Special List of Equipment.

SLOPE DISCRIMINATOR. A circuit giving an output whose amplitude is proportional to the frequency variations of the input signal.

SLOSHING. The dynamic motion of a body of propellant in its tank or container.

SLOT. (1) In aerodynamics, a passage for the fluid flow cut into an airfoil or airframe for the purpose of changing the flow conditions for some particular reason. Slots are used on some wings to increase drag and thus reduce speed for landing. (2) In electronics, an aperture in a waveguide to allow access into a resonant cavity, or to match a waveguide to space for purposes of radiating energy from it. (See **antenna slot**.)

SLOT, ANTENNA. Antenna slot.

SLOW CODE. In range timing, a 9-digit binary system for indicating and/or recording time. According to this system one or more of the 9 pulses are either expanded or allowed to remain at normal size to represent time. Actually there are ten pulses sent out. The leading edge of the first pulse marks the time in question. The next nine pulses by binary representation are either "present" or "absent" (i.e., expanded or normal width) to indicate 1, 2, 4, 8, 16, 32, 64, 128, or 256. When a pulse is indicated as being "present" its value is to be added to the total. See Figure 1

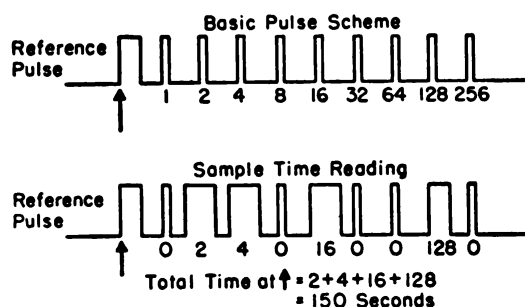


Fig. 1. 9-digit "slow code" timing.

for a sample of this type of timing. Slow code can be used to drive pens on pen and ink recorders, to flash lights on counters or to provide magnetizing pulses for magnetic tapes. (See also **timing**.) A fast code timing results from the use of 10 digits as shown in Figure 2.

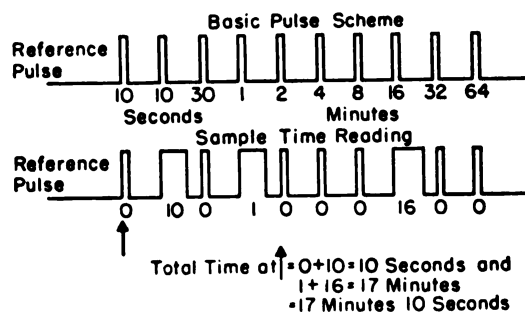


Fig. 2. 10-digit "fast code" timing.

SLUG. A unit of mass; the mass of a body in slugs is equal to its weight divided by the acceleration of gravity.

SLUG TUNING. A means for varying the frequency of a **resonant circuit** by introducing a slug of material into either the electric or magnetic fields or both.

SLURRY FUEL. A liquid fuel (see **propellants**) in which fine solids are suspended.

Sm. Samarium.

SM. Missile, Strategic.

SM-62. Snark.

SM-64. Navaho.

SM-65. Atlas.

SM-68. Titan.

SM-73. Goose.

SM-75. Thor.

SM-78. Jupiter.

SMART. An abbreviation for Supersonic Military Aircraft Research Track, a test installation operated by the U.S. Air Force. The unit was designed and is maintained by the Coleman Engineering Company at Hurricane Mesa, Utah. As of mid-1956, three different sleds were used: MM1 Sled equipped with 3 HVAR's, 3 KS-4500's for acceleration and 6 HVAR's for retro-firing braking; 5 KS Sled equipped with 12 5KS rockets with water braking; and 224B-1 Sled good for Mach 1.7 (or with T-50 Matador booster) good for Mach 2.

SMOKELESS POWDER. A nitrocellulose product of progressive burning characteristics. "Single base" smokeless powder is essentially or entirely **nitrocellulose**. "Double base" smokeless powder contains nitrocellulose and **nitroglycerine**. Smokeless powder comes in the form of granules; in cordite, these are cylindrical in shape.

Sn. Tin.

S-N CURVES. In materials testing, the curves obtained by plotting the number of cycles (N) as abscissa against the load per square inch (S) applied to the test specimen, as ordinate. They illustrate graphically the effect of rapid reversals of stress of definite value on the life of the specimen.

S/N RATIO. Signal to Noise Ratio.

SNAKING. A weaving of an aircraft, missile, etc. from side to side; technically, a persistent directional oscillation of constant amplitude.

SNAP. (Space Nuclear Auxiliary Power.) U.S. Air Force and Atomic Energy Commission projects to develop nuclear auxiliary power sources for satellites and space ships.

The model of the SNAP-III uses 333 milligrams of polonium-210 for a 3 watt output. The operational model of the SNAP-I made to power the television-type scanner in the **Sentry** uses cerium-144 as a radioactive power source. Both models use thermocouples, heated by the decay of the radioisotopes, to produce electric current.

SNARK. A U.S. Strategic Air Command near-sonic, strategic, intercontinental missile of the aerodynamic type. It is officially designated as the Northrop SM-62 (formerly called the XB-62). It has a long, circular fuselage, with a narrow swept-back mid-wing of long, thin tapering design. It is powered by a turbojet engine mounted in the tail. The air intake for the engines form a scoop near the tail, underneath the fuselage. The missile has a single vertical stabilizer and rudder, but no horizontal stabilizer. Lateral stability is achieved by elevons on each wing. This missile is designed to carry nuclear warheads for surface-to-surface missions of 5500 nautical miles. Snark dimensions are: 67 feet 3 inches in length, 15 feet in height, 42 feet 3 inches in span. (See **missile, guided**.) (See also illustration facing Page 410.)

SNARLER. A British rocket motor used as **RATO** for aircraft. Its development was begun in 1946 by the Armstrong-Siddeley Motors, Limited.

SNL. Standard Nomenclature List.

SNORT. Supersonic Naval Ordnance Research Track; Naval Ordnance Test Station; China Lake, California.

SNUBBER. A device to absorb energy at the end of the stroke of an actuator to avoid excessive inertial loading on the part being moved.

SODIUM. Metallic element. Symbol Na. Atomic number 11.

SODIUM PERCHLORATE. A chemical compound of formula NaClO_4 , used as an **oxidizer** in **solid propellant** fuels. It gives a smoky exhaust, and is deliquescent, requiring protection from moisture in storage.

SODIUM PERMANGANATE. An **oxidizer** of formula $\text{NaMnO}_4 \cdot 3\text{H}_2\text{O}$. Its properties

and uses are similar to those of **potassium permanganate**.

SOFAR (SOUND FIXING AND RANGING). A system for determining the point of origin of a sound in water, e.g., the point of impact of a missile, by a sound measuring network. Commonly, an explosive element on the missile gives the necessary sound signal after sinking a prescribed distance.

SOFT STRUCTURE. A structure which is relatively vulnerable to damage from a nuclear explosion usually located on the surface of the ground. (See **base hardness**; **hard structure**.)

SOFT TUBE. Tube, soft.

SOLAR BATTERY. A battery which derives electrical energy from the radiations of the sun, e.g., by use of selenium cells.

SOLAR HEAT. Heat, solar.

SOLAR MOTION. We know that the so-called fixed stars are actually moving in space and in many cases the **space velocity** has been determined. By 1783, the **proper motions** of thirteen stars had been determined and Sir William Herschel noticed that they seemed to have a preferential character. In the direction of the constellation of **Hercules** he noticed that the stars seemed to be moving apart, while in the opposite direction they appeared to be closing in. He interpreted this phenomenon not as a characteristic of the sidereal system as a whole, but rather a perspective effect caused by the actual motion of the sun in the direction of the constellation of Hercules. During the next 50 years the proper motions of many more stars were determined, and in 1837 Argelander discussed the results statistically and confirmed Herschel's determination. With the rapidly increasing number of proper motion determinations during the past century, numerous statistical discussions of proper motions have been made and all have yielded the same conclusion.

With the application of the Doppler-Fizeau principle to the determination of the radial velocities of the stars a method for determining the solar motion independently from the proper motions became available. With increasing number of radial velocity determinations, it is found that stars in the general direction of the constellation of Hercules seem

to have a preferential motion toward the sun, while in the opposite part of the sky the preferential motion is one of recession.

Since all methods for the determination of solar motion are purely statistical in character, it must not be expected that results from different methods will agree exactly. The point toward which the sun is apparently moving is known as the solar apex, while the opposite point on the celestial sphere is known as the solar antapex. Results of statistical analysis of proper motions give the position of the solar apex as **right ascension** 18 hr. 03.1m and declination $+27^{\circ}.0$; while an independent discussion from radial velocities yields 18 hr. 02.4m and $+29^{\circ}.2$. The value of the velocity with which the sun is moving toward this point in the constellation of Hercules is 19.65 kilometers per sec. (12.3 miles per sec.).

Up to the present time there is no conclusive evidence other than that the sun is moving toward the solar apex in a straight line. Many attempts have been made to employ the solar motion for the determination of the distances of the stars. The complete discussion of the problem is far too complex for discussion here but the results which have been obtained, while not of great accuracy for individual stars, are, nevertheless, of great importance for statistical investigations in problems concerned with the discussions of the structure of the **galactic** system.

SOLAR PARALLAX. The mean distance of the earth from the sun is one of the most important constants in astronomical measurement. Known as the **astronomical unit**, it forms the standard of measurement throughout the **solar system**; it is also the base line for the determination of **stellar parallax**. To measure the distance from the earth to the sun directly is obviously impossible and some indirect method must be used. The most common method for the determination of this distance is to determine the angle subtended by an equatorial radius of the earth at the mean distance of the earth from the sun, and this angle is known as the solar parallax.

SOLAR PROBE. A space vehicle for the exploration of the sun. This space vehicle is probably the most intriguing application of **instrumental comets**, at least for the physicist and astrophysicist. It is also an example of the capability of the instrumental comet for

entering regions of space into which manned ships will not be able to follow for a long time to come, if ever. The solar probe could approach the sun as close as about 16,000,000 nautical miles, that is, twice as close as Mercury. The radiation equilibrium temperature of the probe at this distance is 700 to 800°K. , or less if provisions are made to increase the effective emission-to-absorption ratio above 3. This path, therefore, is an extreme example of the motion of solar probes whose perihelion distances would be inside or outside the Mercury orbit. A few of the problems which the solar probe might solve are: the nature of the solar corona (ionization and excitation of coronal atoms); extension of coronal material into space; support and heating of coronal material; electron density in inner and outer corona; electric and magnetic fields in solar space; evaporation of protons and electrons from the corona and solar corpuscular radiation in general and solar cosmic radiation. These and other problems concerning solar phenomena may be solved by solar probes. Their results would have, of course, a most significant bearing on many terrestrial conditions which are affected by solar particulate emission or solar fields.

SOLAR RADIATION. The **radiation** from the sun comprises a very wide range of wavelengths from the long **infrared** rays to the short X-rays, the latter being found far above the Earth, possibly related to the sun's corpuscular radiation (electrons). Since the **air** absorbs the wavelengths toward either end of the spectrum, the solar radiation received on the surface of the earth is confined, largely, to the visible and near infra-red regions, with a very small proportion of the ultra-violet. This is fortunate, for human beings and many other organisms could not endure the full range of solar radiation. The absorption of the shorter radiations takes place largely in the higher stratosphere, where it probably contributes to the atmospheric ionization (see **ionosphere**). The longer infra-red is absorbed mainly by dust and water vapor at lower levels, which accounts for the low temperature of the air at high altitudes.

The intensity, or radiant flux density, of the solar radiation is measured by means of various forms of **pyrheliometer** or solarimeter. Its value is known as the **solar constant** and averages about 1.34×10^6 ergs per sq. cm. per

sec. The direct illumination from the sun approximates 6500 foot-candles.

SOLAR SYSTEM. That group of objects which are moving through space with the sun is known as the solar system. The following classes of objects are listed as members of the solar system, and the details regarding them as individuals will be found elsewhere: **planets, satellites, asteroids, comets, meteors,** and meteorites, and the zodiacal light and gegenschein. The **orbital** and physical data regarding various members of the system may be found tabulated in the article on **planet**. In this article we shall confine ourselves to consideration of the system as a whole.

Examination of the tabular material will indicate several interesting correlations between the various orbital and dynamical factors in the solar system. The mass is overwhelmingly concentrated in the sun, this parent member of the system having nearly 750 times as much mass as all of the rest of the members combined. The distribution of the **moment of momentum**, another important dynamical factor, is interesting in that the four major planets, **Jupiter, Saturn, Uranus, and Neptune**, have about 98% of the total for the whole system. With very few, but nevertheless important, exceptions, the members of the solar system rotate on their axes and revolve, either about the sun, or their primary in the case of satellites, in the same directional sense. Furthermore, the orbital planes of the great majority of the members lie within an inclination angle of 20° to the plane of the **ecliptic**. In so far as we have been able to determine the relative percentages of the various chemical elements which go to make up the various members, the compositions of the different objects bear a remarkable similarity to each other.

For centuries the belief has existed that the solar system is not merely an accidental arrangement of objects in space, but is rather the product of some process of evolution. The mere fact of the common direction of orbital motion of the more than 1300 planets and asteroids is in itself sufficient evidence against any chance arrangement. However, in spite of the labors of the large number of eminent scientists and philosophers, who have worked on the problem during the past three centuries, the origin of the solar system is by no means completely understood.

Since the sun is a typical star, which appears abnormally bright to us merely because of its relatively short distance from the earth, the theories regarding its evolution will be found in the material dealing with the stars. The earliest hypothesis, which is worthy of scientific recognition, is to be found in the writings of Thomas Wright, the theologian Swedenborg, and the philosopher Kant, during the 18th century. None of these gentlemen had much scientific training, with the result that their theories can be regarded as pure hypotheses which violate many of the fundamental principles of dynamics. In the middle of the 19th century the astronomer Laplace attempted to put these hypotheses on a scientific foundation and advanced the so-called Nebular Hypothesis.

In spite of the fact that the Laplacian nebular hypothesis has failed to stand the tests of rigorous analysis and even that Laplace himself gave evidence that he did not regard the theory very seriously, nevertheless, the theory has had such a large popular appeal that a few words regarding it will not be out of place. The theory presumes the existence in space of a large nebulous mass slowly rotating and slowly cooling and condensing. As the mass contracts the angular velocity will increase, since the moment of momentum must be conserved and, with the increase in angular velocity, the centrifugal force at the equator will increase until it becomes greater than the gravitational forces holding the mass together. At this point a ring of matter is split off from the equatorial region of the parent mass. The parent mass continues contracting and increases both the angular velocity and equatorial centrifugal force until another ring is split off. In this way successive rings of matter are produced, each surrounding the equatorial part of the central parent mass. These successive rings of matter split and condense into the major planets with, perhaps, their satellites then formed from the cooling masses in much the same way that the planets themselves were formed. Eventually, the central mass condenses to form the present sun. The common forward motion of all of the planets and their satellites, and the approximately coplanar features of the planetary orbits can all be explained on this theory and it was highly satisfactory to those who did not analyze the mathematics too critically. A careful analysis, however, proves conclusively

that the rings thrown off from the primary would not condense into single planets, but would form swarms of small bodies, such as the **asteroids** or the rings of **Saturn**.

Other considerations regarding the distribution of angular momentum, etc., completely removed the Laplacian theory from the realm of possibility as an evolutionary process for the solar system. Nevertheless many modifications of the Laplacian theory were proposed during the latter part of the 19th century in the vain attempt to satisfy the dynamics of the observed solar system.

With the dawn of the present century a new idea regarding the birth of the solar system was advanced and the three present theories which are worthy of brief consideration are based upon this new conception. It is known that all of the stars are in motion through space relative to each other and more or less at random. From the observed velocities of the stars, their number, and the volume of space which they occupy, it may be calculated that a close approach, and possibly an actual collision is a probable occurrence during the long life history of the average star. The tidal friction theory of Jeans and Jeffries, and the planetesimal theory of Chamberlin and Moulton both assume the close approach of two stars, while the newer theory of Jeffries postulates a "side-swiping" collision. In either case, one of the stars, or what remains after the side-swiping collision, passes off in a hyperbolic orbit; but either the close approach or the collision will have caused the ejection of material from the star which we shall now refer to as the sun. Three different things may happen to this ejected material: much of it will fall back into the sun due to gravitational attraction, some of it will follow the other star out into space, and some of it will remain revolving about the sun. This latter material is the raw substance of which the planets are constructed.

The fundamental difference between the planetesimal theory and the tidal theory is concerned with what happens to the material ejected from the sun very shortly after it was left behind revolving about the sun. Chamberlin and Moulton in their planetesimal theory postulate that the material condensed and solidified relatively quickly into small objects known as planetesimals, while Jeans believes that the material gathered together in the large masses which now form the major

planets. The planetesimal theory then postulates that the planets were formed by the gathering together of the small planetesimals about nuclei and the building up of the planets by a process of accretion. The tidal theory, on the other hand, assumes that the planets were formed by the condensation of large masses of hot diffused material. There are other differences in the theories regarding the distribution of the material about the sun immediately following the catastrophe, but these are too highly technical to be discussed here. The collision theory of Jeffries follows the tidal theory very closely, differing only in the method by which the material was ejected from the sun. None of the theories can be said to be perfect and a great deal of work remains to be done before any positive statement can be made.

SOLENOID. A coil which may consist of one or more layers of windings. It is the basis of all forms of the **electromagnet**, and is thus part of the working-mechanism of many electrically-operated devices.

SOLID PROPELLANT. A rocket fuel in solid form. Desirable qualities to be sought in a solid propellant are high specific impulse, predictable and reproducible performance, wide temperature limits, good storage stability and high mechanical strength. It should be non-hygroscopic, smokeless, non-corrosive, non-toxic, safe and inexpensive to manufacture. Normally the **fuels** used in solid propellants are the asphalts, waxes, oils, resins, and rubbers. The **oxidizers** used are the solid inorganic compounds such as the chlorates and perchlorates, and the organic nitrates and nitro-compounds. To the fuels and oxidizers are added various auxiliary materials: stabilizers to retard decomposition during storage, opacifiers (e.g., lamp black), to reduce heat radiation ahead of the flame, flash depressants, plasticizers and binders. The advantages of solid propellants over liquid propellants are: smaller size and weight, simpler maintenance, longer storage stability in ready condition, and absence of sloshing in the vehicle during maneuvers in flight. Their disadvantages are: higher temperature sensitivity, higher cost, smokier exhaust, and heavier supporting structures. The intermittent operation of solid rockets is difficult, and their overall performances is lower than that of liquid rockets.

SOLID PROPELLANT RAMJET. Rocket, ducted solid propellant.

SOLID-PROPELLANT ROCKET ENGINE OR MOTOR. A rocket engine or motor using a **solid propellant**, i.e., a propellant which is in the solid state before combustion begins. Such motors consist essentially of a motor case (combustion chamber) containing the propellant, and a nozzle for the exhaust jet, although they often contain other components, as grids, liners, etc.

SOLID-STATE PHYSICS. Generally speaking, that branch of physics which deals with the structure and properties of solids. It may perhaps be divided into the anatomy of solids, i.e., crystallography, theory of the structure of metals, alloys, ionic crystals, etc., cohesive forces, band structure, etc.; the physiology of solids, i.e., specific heats, thermal vibrations, thermal and electrical conductivity, intrinsic semiconductivity, superconductivity, photoconductivity, magnetic and dielectric properties, etc.; the pathology of solids, i.e., impurity semiconductivity, plasticity, lattice defects, color centers, dislocation theory, crystal growth, etc. One may observe a shift of interest from the former to the latter aspects, as understanding of the solid state progresses.

SOLION. Any of several electrochemical devices depending upon the properties of ions in a solution (instead of in a gas or vacuum), used for electrical controls. In one form an iodine solution is used. The ion flow conditions can be made sensitive to temperature, pressure, light, sound and acceleration. The weight of these devices is only a few ounces, and their size is equivalent to that of a small electron tube. They can be used to replace transistors and vacuum tubes, but only for low frequencies (up to 200 cycles per second). They have possible applications in **inertial navigation**.

SOLUTION CERAMIC. A non-brittle, inorganic **ceramic** coating containing no bonding agent and capable of application at low temperatures. (Typical solution ceramics: zirconia, chromia, titania, ceria, etc.)

SOMMERFELD FORMULA. An approximate radio propagation relationship for distances short enough that the earth's curvature may be neglected. It states that

$$\varepsilon = \frac{K\sqrt{PA}}{d}$$

where ε is the field strength; K is an antenna constant; P is the radiated power, d is the distance away from the antenna and A is relationship involving the frequency, the distance, and the soil conductivity.

SONAR (SOund Navigation And Ranging). Equipment employed for underwater detection, ranging, and depth measurement. In a process analogous to that used in radar, sonic or supersonic pulses are transmitted, reflected from an object, and received at the point of transmission. The required time-interval is used as a measure of the distance between the reflecting object and the transmitter. **Transducers**, which are analogous to radar antennas, are used to propagate and receive the sound energy.

SONCM. Sonar Countermeasures and Deception.

SONDE. In telemetering, the complete airborne telemetering system in the vehicle. A radiosonde is a telemetering set sent aloft in a container raised by a small balloon for the purpose of making upper air observations, and transmitting these to ground stations automatically as the balloon rises.

SONE. A unit of loudness. It is a simple tone of 1000 cycles per second, 40 **decibels** above a listener's threshold. The loudness of any sound judged by the listener to be n times that of the 1-sone tone is " n sones loud." It is a subjective unit.

SONIC. Of or pertaining to sound. Sonic velocity is the velocity of sound.

SONIC BARRIER. The usual name for the **transonic barrier**.

SONIC BOOM. A noise caused by a shock wave emanating from an aircraft or other object traveling at or above the speed of sound. A shock wave is a pressure disturbance and is received as a noise or clap by the ear. The "boom" is really the same effect as the "crack" of a rifle bullet passing overhead or beside a person, except that it is a sound made by a much larger body. The sound can create minor damage, and if sufficiently close can injure ear drums of persons exposed. (See Fig. 1, Page 571.)

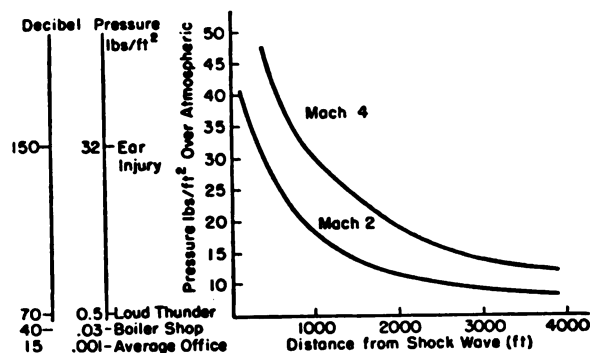


Fig. 1. Sonic boom hazard.

SONIC, HYPER- (HYPERSONIC). (1) Aerodynamic flow at high supersonic velocities, of the order of Mach 5 or greater. (2) Velocities at which time of missile passage is of the same order as *relaxation time*, i.e., the time for gas molecules to reach equilibrium after sudden change in conditions. In such a domain, gases must be treated as discrete particles rather than a continuum. Measurements of relaxation times of gases are incomplete, but there are indications that Mach numbers of the order of ten must be regarded as hypersonic. Velocities that are not hypersonic at sea level may become so at high altitude, as relaxation times will be longest where densities are relatively low.

SONIC NOZZLE. A nozzle converting a high pressure gas to a supersonic flow in which the velocity of gas at the throat is equal to the velocity of sound.

SONIC SPEED. The speed of sound in air. In ambient air, with ratio of specific heats assumed 1.4 and the air following the gas law with temperature in degrees Rankine, the speed of sound is $33.42 \sqrt{T}$ miles per hour, or $29.02 \sqrt{T}$ knots; with temperature in degrees Kelvin, the speed of sound is $44.84 \sqrt{T}$ miles per hour, or $38.94 \sqrt{T}$ knots. The speed of sound in air carries with the density, and hence also with altitude. (See Fig. 2.)

SONIC, SUB- (SUBSONIC). Less than the speed of sound or less than a Mach number of one.

SONIC, SUPER- (SUPERSONIC). Faster than the speed of sound. When supersonic speed is attained by a moving object, no advance information in the form of advance

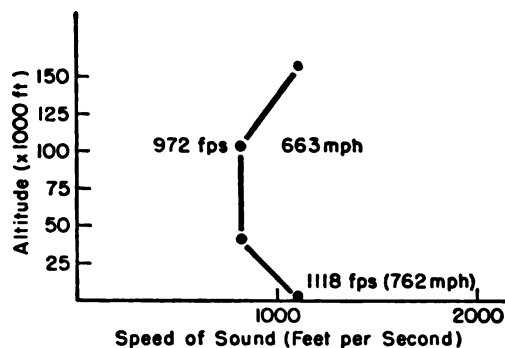


Fig. 2. Speed of sound—variation with altitude.

pressure waves can be given to the air, as the body is moving faster than the pressure waves emanating from the body can propagate forward. As a result, shock waves are formed which move with the body and are attached or unattached depending on the conditions. (See **shock wave**.)

SONIC, TRAN- (TRANSONIC). The intermediate speed in which the flow patterns change from subsonic flow to supersonic, i.e., from Mach numbers of about 0.8 to 1.2, or *vice versa*.

SONNE. A radio navigation system providing a number of equi-signal zones which rotate in time sequence, so that a navigator may determine his true bearing from the transmitter by observation of the instant at which he hears the equi-signal.

SONOBUOY. A floating radio transmitter modulated by a **programmer**, acoustic transducer, etc. depending upon its use. It is used (1) for release from a sunken submarine to indicate its position; and (2) for gathering and transmitting local data from the surface of a hazardous or remote water area such as radio active sea water (3) for gathering (actively or passively) intelligence on a submerged submarine. These may be dropped from aircraft or ships.

SOP. Standing Operating Procedure.

SOUND. (1) An alternation in pressure, stress, particle displacement, particle velocity, and so forth, which is propagated in an elastic material, or the superposition of such propagated alterations. (2) Also, auditory sensation which is usually evoked by the alterations described above. In case of possible confusion the terms "sound wave" or

"elastic wave" may be used for concept (1), and the term "sound sensation" for concept (2).

SOUND (ACOUSTOMOTIVE) PRESSURE.

The *instantaneous sound pressure* at a point is the total instantaneous pressure at the point minus the static pressure. The unit is the dyne per square centimeter. The *effective sound pressure* at a point is the root mean square value of the instantaneous sound pressure over a complete cycle at the point. The unit is the dyne per square centimeter. The *peak sound pressure* for any specified time interval is the maximum absolute value of the instantaneous sound pressure in that interval. The unit is the dyne per square centimeter. The *maximum sound pressure* for any given cycle is the maximum absolute value of the instantaneous sound pressure during that cycle. The unit is the dyne per square centimeter.

SOUND-POWERED PHONE. A point-to-point telephone communicating system employing no batteries, amplifiers or other means of external power. The human voice produces a sound wave which actuates the microphone at the transmitting end. The microphone converts the acoustic energy into the corresponding electric energy. This energy is carried on wires to the receiving end, where the electrical variations are converted into sound vibrations by the receiver.

SOUND TRACK. A narrow band, usually along the margin of a sound film, which carries the sound record. In some cases, a plurality of such bands may be used.

SOUNDING ROCKET. Rocket, sounding.

SOURCE. Any device which supplies energy, in the form of radiation, electric currents, sound waves, etc. Thus, in spectroscopy, the arc or spark that supplies light; in electrical circuits the generator, battery, or oscillator that supplies electrical energy; in sound recording, the device which supplies power to a transducer.

SOURCE IMPEDANCE. The apparent impedance of a signal source. It may or may not be equal to the recommended load impedance. The lower the source impedance, the better the voltage regulation. (*Inverse feedback* in an audio power amplifier reduces

source impedance, resulting in better speaker damping.)

SPACE. In ordinary terms, the void between celestial bodies in the general region beyond the sensible atmosphere of the earth. In specific terms, *near space* is the first region beginning at an altitude of about 120 miles; *deep space* is the region beyond this, which includes the moon; and *outer space* is the interplanetary region where the significance of the earth as a primary no longer exists. (The *exosphere* begins at approximately 350 miles altitude; some definitions observe the convention that "space" does not begin until past it.) In other designations, *outer space* is the region between galaxies, *middle space* is the region between stars of a galaxy, and *inner space* is the realm within the system of planets. Space may also be described in compound terms referring to particular astronomical bodies—some of these terms being given among the entries following.

SPACE CABIN. A pressurized and climatized cabin for use in space flight.

SPACE CHARGE. The electric charge carried by a cloud or stream of electrons or ions in a vacuum or a region of low gas pressure, when the charge is sufficient to produce local changes in the potential distribution. It is of importance in thermionic tubes, photoelectric cells, ion accelerators, etc.

SPACE, CISLUNAR. Space inside the lunar orbit.

SPACE, CIS-PLANETARY. Space between the earth's orbit and the orbit of the respective planet; e.g., cis-Martian space is the space between earth and Mars; cis-Venusian space is the space between earth and Venus.

SPACE, EXTRA-PLANETARY. Space beyond the particular planetary orbit as seen from the sun: e.g., extra-trans-Plutonian space.

SPACE FLIGHT. The science of extra-terrestrial flight of unmanned vehicles. Contrast with *space travel*. (See *astronautics*; *cosmonautics*.)

SPACE FLIGHT, MANNED, ENERGY REQUIREMENTS. The primary objective of the development phase of manned space flight

is the ability to return from an orbit to the earth's surface. This appears technically possible by using atmospheric braking. A much more desirable way is to use reverse thrust but this creates, for the first time, the inherent demand of the manned space flight vehicle for much more energy than is needed in the unmanned vehicle. A second high energy requirement results from those missions which manned space flight alone can undertake; the physical exploration of the surfaces of other planets and the exploration of the outer solar system. The manned vehicle, in contrast to its automatic predecessor, must return to earth. This doubles the flight energy requirement. If landings on a target planet are contemplated, the energy requirement is further increased, at least for accomplishing takeoff from the earth's surface, if not for the descent. The third (and by far the greatest) energy requirement is derived from the crucial demand for reducing the long transfer times which characterize the minimum energy trans-

fer paths. The exploration of the solar system depends upon the solution of this problem, since few people will be inclined to spend their lifetimes within the narrow confines of a space ship, traversing the immense interplanetary space in darkness to Neptune or Pluto. There is only one solution: much more energy.

In consequence of these three energy requirements, it is a simple fact that manned space flight, particularly manned interplanetary flight, depends primarily upon the development of high-energy propulsion systems.

SPACE FLIGHT PROPULSION SYSTEMS.

The accompanying chart (Fig. 1) correlates altitudes (or distances) and energy levels (in terms of velocity), and indicates the "minimum" propulsion systems required within practical technical limits of vehicle design. All terrestrial and orbital (satellite) operations up to lunar flight can be carried out with chemical propellants. In interplanetary

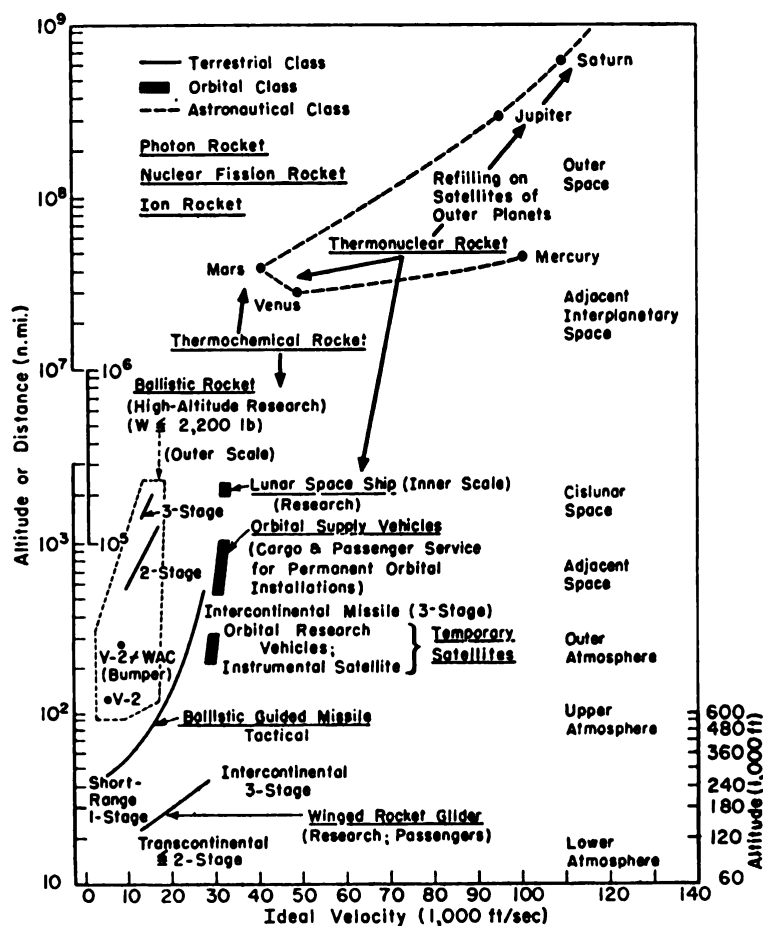


Fig. 1. Space flight. Ideal velocity distance relationships for rocket propulsion systems.

flight the practical limits for thermochemical propulsion systems are our two neighboring planets Venus and Mars. Beyond the adjacent interplanetary space more powerful propulsion systems will be needed, not only in order to permit such excursions with technically feasible mass ratios, but also in order to reduce the very long travel times obtained for round trips, if the flight path in an ellipse whose apsides are located in the orbits of earth and target planet, respectively. (See Fig. 2.) It may be noted that the interplanetary energy levels indicated in these two figures are representative values only, but they designate approximately the upper limits for the co-tangent flight ellipse mentioned above. It is likely that more advanced propulsion sys-

tems of not too low thrust-to-weight ratio will be used ultimately in earth-moon space. In this case, the expendable, or thrust, mass consumption would be reduced considerably. For earth-moon commutation as it will develop after establishment of a lunar base, the running costs (earth-to-orbit supply of expendable material) must be minimized if the economy of such a system is to be realized at all. For interplanetary transfer, chemical propellants are not likely to be used, certainly not on a regular flight basis, because of the high consumption of thrust mass. This general statement leaves many problems unsolved. These problems not only involve the application of known engineering principles, or of available scientific knowledge, to advanced

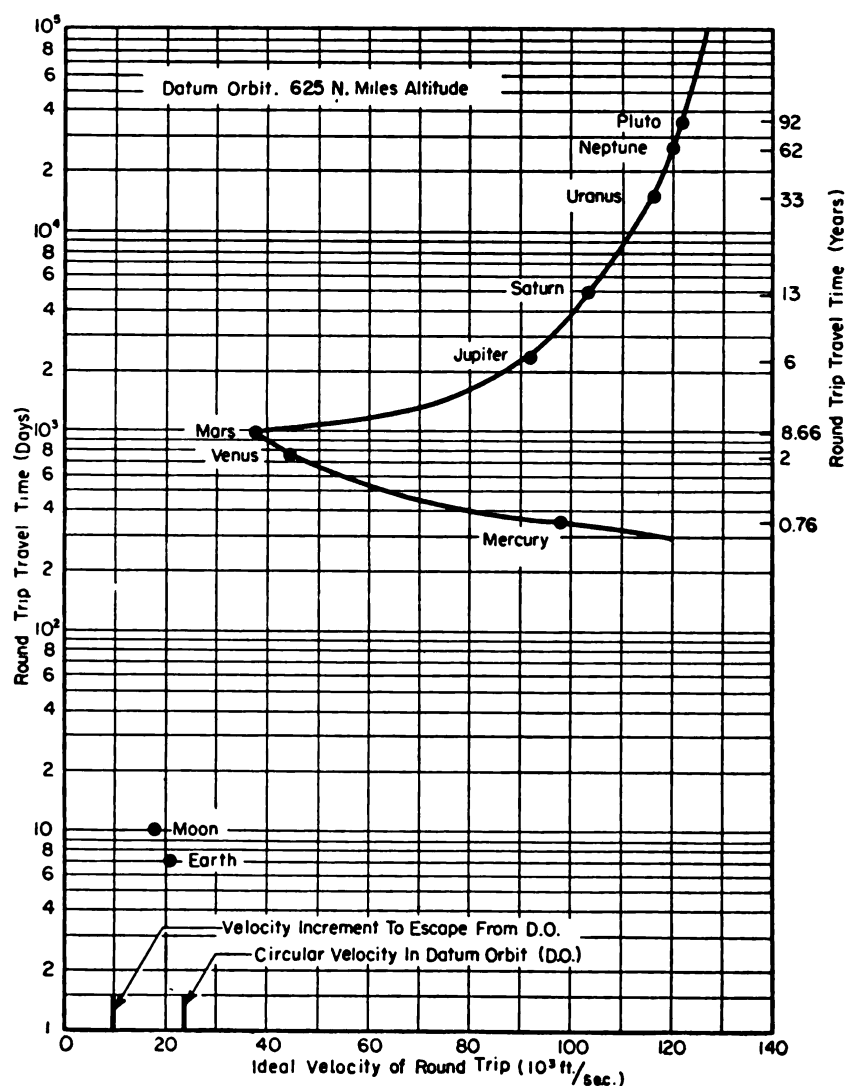


Fig. 2. Space flight. Approximate minimum energy requirement and maximum travel time for round trips to other celestial bodies.

engineering concepts; even more significant are those problems which require the initiation, specification and coordination of scientific research to meet engineering requirements. Indeed, the development of man's space flight rests on a thorough integration of science and technology.

SPACE FLIGHT REQUIREMENTS. In order to carry out successfully a given space flight mission, the following three conditions must be met: (1) The energy requirements must be known; (2) The propulsive energy available must match the (flight) energy required for the specified payload; (3) The physical means for synthesizing a minimum spacecraft must be available; that is, a set of adequately developed structural, propulsion and guidance systems and related components.

SPACE, GALACTIC. Interstellar space, in general within the respective galactic system.

SPACE, INTERGALACTIC. Space between galaxies.

SPACE, INTERPLANETARY. Space between the planets.

SPACE, INTERSTELLAR. Space between stars or solar systems.

SPACE, INTRA-PLANETARY. Space between the sun and the orbit of the respective planet: e.g., intra-Mercurial space.

SPACE LABORATORY. 1. A space vehicle carrying sensing and measuring instruments, recording equipment, radio-transmitting equipment, and other related instruments, used as a means of obtaining scientific data on conditions in the upper regions of the earth's atmosphere or in outer space. 2. A vehicle that simulates the conditions of a space vehicle.

SPACE, LUNAR (CISLUNAR). Space inside the lunar activity sphere with respect to the earth.

SPACE MEDICINE. An extension of aviation medicine concerned with the study, prevention, cure or alleviation of illnesses or diseases expected to arise from space flight.

SPACE, PLANETARY. Space in the close vicinity of the respective planet, in the same

sense as defined for terrestrial space. (See **space, terrestrial**.)

SPACE PROBE. A research vehicle intended to reach a distant point in space, possibly to return to Earth, or to impact on some distant celestial body, or to escape from the solar system.

SPACE SHIP, OR SPACESHIP. A craft or vehicle designed for travel beyond the earth's atmosphere.

SPACE STATION. A platform or structure put into orbit about the earth or other primary celestial body, intended especially to service space ships, to provide a facility for the beginning of an interplanetary flight, etc.

SPACE, TERRESTRIAL. The region roughly between 200 and 3,500 miles (1 earth radius) altitude dominated practically exclusively by terrestrial gravitational and geophysical phenomena.

SPACE, TRANSLUNAR. Space outside the lunar orbit but within the limit of the earth's activity sphere with respect to the sun.

SPACE, TRANS-PLANETARY. Space beyond the volume of the particular planetary orbit as seen from the earth: e.g., Mercury's orbit lies in the trans-Venusian space.

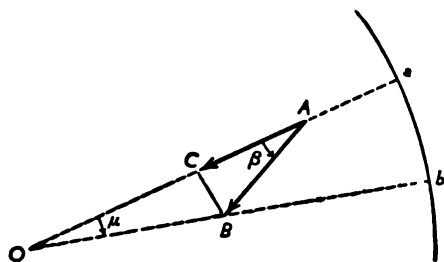
SPACE TRAVEL. The science of extra-terrestrial flight of manned vehicles. Contrast with **space flight**. (See **astronautics**; **cosmonautics**.)

SPACE VEHICLE. (1) An artificial body operating essentially or exclusively outside the earth's atmosphere; technical requirements and mission are determined by space conditions. (2) *Instrumental*: A pilotless or unmanned space vehicle. (3) *Manned*: Occupied for a comparatively short time (also: piloted). (4) *Inhabited*: Occupied for days or longer.

SPACE VELOCITY. The space velocity of a star is its actual velocity in space relative to the sun. The term "fixed star" is one which has been handed down to us from the era when philosophers believed that the stars were fixed on a sphere, rotating about the earth, which they referred to as the celestial sphere. At the present time we believe that practically all of the stars are actually in motion in space

with velocities comparable in magnitude to the velocities with which the **planets** are moving about the sun in their orbits. In measuring any velocity it is necessary to have a definite reference point and the space velocity of a star is its velocity referred to the sun.

In the figure we have the space velocity of



a star represented by the **vector** (directed straight line proportional to the velocity in direction and magnitude) AB . The angle β which this vector makes with the direction of the star from the sun at any particular instant gives the direction of the space velocity at that instant.

As observed from the solar system this space velocity may be resolved into two components: AC the **radial velocity**, and μ the **proper motion**. The radial velocity is determined directly in terms of linear velocity (i.e., in miles or kilometers per sec.) but the proper motion may only be determined in angular units, usually expressed in seconds of arc per year. In order that the space velocity may be known the proper motion must be converted into a linear velocity, commonly known as the transverse velocity of the star. This may be accomplished only if the distance of the star is known. Expressing the distance in terms of the stellar parallax, P'' , and calling the transverse velocity T (the line CB in the figure), the following relations may be derived:

$$T = 4.74 \mu / P'' \text{ kilometers/sec.}$$

or

$$T = 2.94 \mu / P'' \text{ miles/sec.}$$

With both the transverse velocity, T , and the radial velocity, R , known in the same units, the problem of determining the space velocity S in the same units is merely that of solving the plane right-triangle ACB . This solution yields:

$$S^2 = T^2 + R^2 \quad \cos \beta = R/S \quad \sin \beta = T/S.$$

SPACECRAFT. A craft designed to travel in space beyond the earth's atmosphere. **Space ship** is the more common term.

SPACISTOR. An invention of the Raytheon Manufacture Company, Waltham, Mass. It is a semi-conductor about the same size as a transistor, having a higher temperature and high frequency range of operation. It is used to amplify frequencies up to 10,000 megacycles per second, and can operate at temperatures as high as 500°C (932°F).

SPACESHIP. **Space ship.**

SPACESUIT. A suit designed especially to protect the body in the vacuum of outer space.

SPACE-TIME. A four-coordinate space (3 space coordinates, and 1 time coordinate) in which an event occurs. (See **relativity**.)

SPAEROBEE. A design proposed by the Aerojet General Corporation in the fall of 1956. The design envisioned a two-stage rocket using an **Aerobee** as the first stage and a **Sparrow** for the second stage. This combination was thought capable of a 400 mile altitude with about 50 pounds of payload. The complete vehicle would be about 375 inches long.

SPALLATION. **Fission, nuclear.**

SPAN. The tip-to-tip distance across an **air-foil**.

SPARK. An electric spark is a sudden breakdown of the insulating strength of the dielectric separating two electrodes, due to the formation of ions by an intense electric field, accompanied by a rush of electricity across the "spark gap," and a flash of light indicating very high temperature. Unlike the arc, glow, and brush discharges, the spark is of very short duration. It may be oscillatory or intermittent, several discharges taking place in quick succession. In gases, the spark takes place only at appreciable pressures, such as normal atmospheric pressure.

SPARK I. An intermediate altitude sounding rocket (IASR), developed by the Rocket Research Institute, Sacramento, California, for the International Geophysical Year experiments. It was a two-stage vehicle, consisting of a first stage booster of a solid propellant

type having 5000 pounds thrust, and a second stage of 350 pounds thrust burning liquid oxygen and alcohol. This combination was designed for altitudes above 100,000 feet.

SPARROW. An family of air-to-air guided missiles. The Sparrow appeared in various forms under the general aegis of the U.S. Navy Bureau of Aeronautics. This missile had an overall weight of approximately 300 pounds, and was boost-glide propelled by a double-base solid propellant rocket. It was designed to be used by carrier-based aircraft over ranges of approximately 5 miles. The various models used various guidance schemes, some including homing in the terminal phase. Sparrow I was a beam-rider developed by the Sperry Gyroscope Co. This version was approximately 12 feet long, weighed about 300 pounds and employed a velocity of about 1500 miles per hour. Sparrows II and III were later models by the Douglas Aircraft Co. and Raytheon Mfg. Co. respectively. (See **Missile, guided.**) (See also illustration facing Page 410.)

SPATIOGRAPHY. The science that describes the character of space, including the location and gravitational effects of the celestial bodies, primarily from the point of view of **rocketry** or **astronautics**. It emphasizes, therefore, the regions of space to be traversed by **missiles** or **space ships** from earth, and may include the study of the regions of radiation, magnetism, etc. surrounding the earth.

SpecDevCen. Special Devices Center; Bureau of Aeronautics; Department of the Navy.

SPECIAL LIST OF EQUIPMENT (SLOE). A military publication that establishes temporary equipment allowances. It also may be used to authorize nonstandard equipment on a continuing basis.

SPECIFICATION, DETAIL. A detail description of a particular model missile prepared by the designer which cites all specific design and construction criteria.

SPECIFICATION MODEL. Model specification.

SPECIFICATION PERFORMANCE. Performance specification.

SPECIFICATION TREE (OR CHART). A scheme for categorizing the specifications re-

quired for a weapon system to show the interrelation.

SPECIFIC FUEL CONSUMPTION. (1) In thermal engines, the mass of fuel used relative to an appropriate unit of output: jet engines usually are rated in pounds (fuel) per pounds (thrust) per hour, while reciprocating engines are rated in pounds (fuel) per horsepower-hour. (2) The reciprocal of **specific impulse**; pounds per pound second. Sometimes termed the "performance index."

SPECIFIC GRAVITY. The ratio of the weight of a given volume of a substance to the weight of an equal volume of water at standard conditions.

SPECIFIC IMPULSE (I_{sp}). In rocketry, a parameter indicative of efficiency: a property of the propellant combination and the mixture ratio. Specific impulse is equal to pounds of thrust developed per pound of propellants consumed (fuel plus oxidizer) per second, or the ratio of thrust to propellant mass flow. (See **specific impulse, ideal**; **total impulse**.)

SPECIFIC IMPULSE, AIR. A figure of merit for a jet engine propelling a guided missile; expressed as pounds of thrust per pound of fuel consumed each second; the ratio of the critical stream thrust (at a Mach number of unity) to the air mass flow.

SPECIFIC IMPULSE, FUEL. In rocketry, the thrust developed by burning one pound of fuel in one second, or the ratio of the thrust to the fuel mass flow.

SPECIFIC IMPULSE, IDEAL OR THEORETICAL (I_{sp}). The maximum reliable impulse obtainable from a given combination of propellants; calculated from thermo-chemical relations. The difference between the ideal and measured specific impulse (I_{sp}) is due to heat losses, incomplete combustion of propellants, flow losses and variations in back pressure. I_{sp} usually ranges from 0.93 to 0.98 of I_{sp} .

SPECIFIC IMPULSE, OVER-ALL. In rocketry, the impulse per unit total weight of system.

SPECIFIC PROPELLANT CONSUMPTION. In a rocket motor, the amount of weight flow required to produce one unit of thrust, i.e., the reciprocal of **specific impulse**.

SPECIFIC PROPELLANT CONSUMPTION. In rocket propulsion, a term expressing the rate of burning of propellants per unit of thrust. Its units are reciprocal time. Mathematically:

$$SPC = \frac{dw/dt}{F} = \frac{1}{I_{sp}} = \text{sec}^{-1} = \frac{3600}{I_{sp}} \text{ hour}^{-1}$$

The term gives a method of comparing the efficiency of different kinds of motors. Specific propellant consumption is given by:

$$\begin{aligned} SPC &= \frac{\text{pounds of propellant}}{\text{pounds thrust} \times \text{hours}} \\ &= \frac{(dw/dt) \times 3600}{F} = \text{hours}^{-1} \end{aligned}$$

The reciprocal of *SPC* is the **specific impulse**.

SPECIFIC SPEED. A design parameter used in high-speed, rotating pump calculations.

$$N_s = N \frac{Q^{1/4}}{h_v^{1/4}} \text{ rpm.}$$

where *N* is the speed in rpm, *Q* is the pump output in gpm, *h_v* is the rise in pump head, inlet to discharge, in feet.

SPECIFIC THRUST. Thrust, specific.

SPECIFIC WEIGHT FLOW. In a rocket motor, the weight flow per unit throat area.

SPECTRAL CLASS. Examination of stars with the unaided eye will indicate that they are not all of the same apparent color. This fact has been noticed from earliest times, and we find the names of many of the stars carrying an indication of their color, e.g., *Antares* was undoubtedly so named because of its reddish color similar to that of the planet Mars. With the application of the **spectroscope** to astronomical research, several attempts were made to classify the stars according to their spectra. Secchi and Vogel each proposed spectral classification sequences based upon visual observations. The system which is now universally employed was developed by Dr. E. C. Pickering, Director of the Harvard College Observatory from 1877 to 1919. The first results of his classification were published by the observatory with funds made available by Henry Draper, and the classification system is known either as the "Harvard system" or as the "Henry Draper system."

The Harvard system of classification is based upon the relative intensity of certain selected **absorption** lines in the stellar spectra. The various types are designated by letters, and the principal characteristics of the different classes are:

Class B—Helium stars—Absorption lines of helium and hydrogen characteristic features.

Class A—Hydrogen stars—Intensity of helium lines weaker and hydrogen lines the most prominent feature.

Class F—Calcium stars—The *H* and *K* lines of calcium are much stronger than the hydrogen lines, although the latter are still prominent. A few metallic lines are present.

Class G—Solar Stars—Calcium lines the most prominent feature, with the hydrogen lines distinctly fainter. Many metallic lines.

Class K—Metallic lines—Calcium lines still strong but spectrum predominated by multitude of lines due to metals. The violet end of the continuous background distinctly weaker.

Class M—Molecular compound lines—Calcium and many metallic lines still prominent, but characteristic feature is the presence of bands due to molecular compounds. The violet end of the continuous background extremely weak.

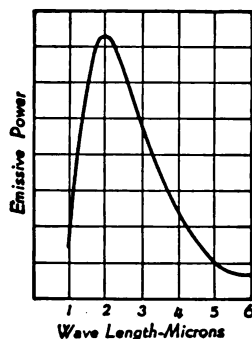
Accompanying the above changes in the absorption lines there is a progressive change in the position of maximum intensity of the continuous background, the colors of the stars changing from blue for the B-type through yellow for the G-type to red for the M-type. This is an indication of a temperature sequence for the stars, those of the B-type being hottest and those of the M-type coolest. Ninety-nine per cent of all stars thus far examined may be fitted into this sequence of six letters. Stars with spectra intermediate between the various types are designated by a decimal system, e.g., a G5 star is half way between a G- and a K-type star. To provide for the few stars which cannot be fitted into the main sequence there are a number of small classes. For example, certain blue stars, some of which show bright lines, are known as O-type or W-type, the Wolff-Rayet stars; while red stars other than M-type, are grouped under N, R, and S.

More than 400,000 stars have been classified at the Harvard Observatory on the foregoing system. The spectra were obtained by objective prism photography, and examined

and classified by Dr. Annie J. Cannon. These results are published in the Henry Draper Catalogue and its extensions. Other observatories, using objective prisms, or large reflectors and slit spectrographs, have classified large numbers of stars fainter than those included in the Henry Draper Catalogue, and have also made critical examinations of high dispersion spectra to determine slight differences within the individual classes. The correlations between spectral type and the physical characteristics of the stars will be found in the article on **giant and dwarf stars**.

SPECTRAL ENERGY DISTRIBUTION.

When radiation exhibiting a continuous spectrum is quantitatively analyzed, it is found that quite different amounts of power are represented by the radiation within equal ranges of wavelength or of frequency having different limits. The proportion in any such range depends upon the character of the source. If one divides the spectrum into small intervals



of wavelengths, say 10 angstroms, and plots the power output for each range as ordinate with the mean wavelength of the interval as abscissa, the result is a curve showing the distribution of power through the spectrum. (See **Planck distribution law**.)

SPECTROGRAPH. An instrument used to produce a record of a **spectrum**. It may be considered to include the apparatus for producing the radiations or particles to be investigated; and includes the other necessary apparatus, i.e., that for selecting a desired portion of the radiations or particles; that for arranging them in a uniform beam; that for separating the beam into a spectrum; and that for recording the spectrum by photographic or other means. (See also **spectroscope**.)

SPECTROHELIOGRAPH. As the construction of the term indicates, the spectroheliograph pictures the sun in its **spectrum**. Essentially the instrument consists of a high dispersion spectrograph with a second slit placed directly in front of the photographic plate so that the radiation from only one spectral line is received on the plate. If the instrument is so placed that the first slit is in the principal focus of a telescope directed toward the sun, a narrow strip of the sun's image will be admitted by the first slit and an image of that narrow section of the sun will be formed on the photographic plate in the particular radiation for which the second slit is adjusted. The instrument is so constructed that the first slit may be moved across the image and at the same time the second slit moves across the photographic plate at the same rate. Hence, it is possible to obtain a photograph of the sun in the monochromatic radiation of any particular element, say calcium.

From the **flash spectrum** we can determine the heights to which various elements rise in the solar atmosphere, and thus by means of the spectroheliograph it is possible to obtain photographs of the sun at various levels above the **photosphere**.

SPECTROMETER. An instrument used to measure spectra or to determine **wavelengths** of the various radiations.

SPECTROSCOPE. An instrument for producing and viewing spectra.

SPECTROSCOPIC BINARIES. Within the past 70 years we have become acquainted with a class of **binary stars** which are not **double stars** in the ordinary sense of the term, because of the fact that the components are too close together for them to be observed separately even in telescopes of the highest resolving power. In such binaries the period is usually short and the orbital velocities high. Unless the orbit plane happens to be perpendicular to the line of sight, the orbital velocities will have components in the line of sight and the observed radial velocity of the system will vary periodically. Since radial velocity is measured with the spectroscope, employing the Doppler-Fizeau principle, the binaries so observed are known as spectroscopic binaries. In some spectroscopic binaries the spectra of both stars are visible and

the lines are alternately double and single. Such stars are known as double-line binaries. In others the spectrum of only one component is seen and the lines in this spectrum move periodically from violet toward the red and back again.

SPECTROSCOPIC PARALLAX. The term spectroscopic parallax of a star is applied to a determination of the distance of a star in which the **stellar parallax** is determined from observations of spectral peculiarities of the star together with determinations of the apparent brightness of the object.

The apparent brightness of a star depends upon two fundamental factors: the intrinsic brightness of the star and its distance from the observer. Expressed on the **stellar magnitude** scale, we find the apparent magnitude, m , the absolute magnitude, M , and the stellar parallax π'' , to be connected by the analytical expressions: $M = m + 5 + 5 \log_{10} \pi''$. The apparent magnitude of a star may be determined by a variety of methods of **stellar photometry**, and if a method is available for the determination of the absolute magnitude the value of the stellar parallax may be determined.

The relative intensities of certain spectral lines are different in **giant and dwarf stars** of the same spectral type. The relative intensities of selected pairs of lines may be compared in stars of the same spectral type and known absolute magnitudes and a "calibration curve" obtained. The relative intensities of the same pairs may then be found in stars of unknown absolute magnitudes and the calibration curves used to determine the absolute magnitude. Thus, the parallax may be determined from a study of spectra. The accuracy of the determinations of spectroscopic parallax compares very favorably with parallaxes obtained from the relative trigonometric methods.

SPECTRUM. (1) A visual display, a photographic record, or a plot of the distribution of the intensity (and sometimes the phase) of radiation of a given kind as a function of its wavelength, energy, frequency, momentum, mass or any related quantity. (2) A continuous range of frequencies usually wide in extent, within which waves have some specified common characteristic, e.g., audio-frequency spectrum, radio-frequency spectrum,

etc. (3) The resolution pattern of a group of masses over a region according to increasing mass, in which particles of a given mass are physically isolated from those of neighboring masses. (4) A mathematical concept denoting the types of resolutions which are associated with a given partial differential equation.

SPECTRUM, MAGNETIC. A term sometimes applied to particles (such as iron filings) spread out in a **magnetic field**, and distributed so as to show **lines of force**.

SPECTRUM, MICROWAVE. A spectrum of wavelengths lying in the region between the far **infrared** and the conventional radio-frequency region. The boundaries of the microwave region have not been definitely fixed, but it is commonly regarded as extending from about 0.1 cm to 30 cm in wavelength, representing about 8 octaves of the electromagnetic spectrum.

SPEED. The magnitude of the vector **velocity**. Speed is a scalar quantity and is expressed in units of length divided by time.

SPEED, CRITICAL. (1) The speed of a rotating object, commonly a major part of a machine or engine, at which it oscillates at a resonance frequency. Often more than one critical speed exists, although at different frequencies of oscillation. (2) The speed of a flight vehicle beyond which a catastrophic failure will occur.

SPEED OF RESPONSE. Time constant.

SPEED OF SOUND. Sonic speed.

SPHEREDOP. A DOVAP trajectory measuring system using a stable missile **oscillator** rather than a transponder.

SPHERICAL-EARTH FACTOR. The ratio of the **electric field strength** that would result from propagation over an imperfectly-conducting spherical earth to that which would result from propagation over a perfectly-conducting plane.

SPHERICAL-TRIGONOMETRIC COMPUTER. Computer, spherical-trigonometric.

SPIKE. (1) In supersonic aerodynamics, a spike is a sharp-pointed lance-like object designed to point into the flow stream for the

purpose of diffusing the impact of the stream. For example, the nose probes of supersonic aircraft designed to reduce **shock wave** formation are called spikes, as are the sharp-pointed center-body **diffusers** used in ramjet engine intakes. (See **Diffuser**, **Oswatitsch**.) (2) In electronics, any sharp signal which transcends the ambient noise.

SPILLOVER. That portion of the air in the stream-tube which flows to the side of a ramjet intake rather than through the intake. This occurrence takes place under conditions of detached shock. Under conditions of *attached* or *swallowed shock*, there is no spillover. (See illustration in entry on **diffuser**.)

SPIN. To rotate about an axis. In aerodynamics, the axis is usually taken parallel to the direction of flight, the longitudinal axis of a rocket or missile.

SPIN STABILIZATION. A technique for stabilizing a missile during boost, midcourse or terminal phases in which a slow spin is used to eliminate dispersion due to misalignments. Appropriate discrimination of guidance intelligence is required to insure proper control in each plane.

SPIRAL. In astronomy, the use of the term spiral is as follows. For many years the extra-galactic **nebulae** were known as spiral nebulae, but recent researches have proved conclusively that they are a totally different class of objects from the galactic nebulae. Their spectra, instead of being characterized by the bright lines commonly found in the galactic nebulae, are of the absorption type such as would be produced by a large number of stars of various **spectral classes**. Long-exposure photographs of the extra-galactic nebulae, taken with instruments of long focal length, have definitely proved the hypothesis that these objects are in reality large groups of very distant stars, i.e., they are galaxies.

In at least five of the extra-galactic nebulae **Cepheids** have been discovered, and the application of the period-luminosity relation for Cepheids gives distances of between 100,000 and 1,000,000 **light years** from the sun. By various statistical methods, largely developed by Hubble at the Mount Wilson Observatory, the distances of a number of other extra-galactic objects have been obtained. Distances of the order of magnitude of one billion

(1,000,000,000) light years have been obtained. Although this figure approaches the limit of spectroscopic measure with the 200-in. telescope, it is hoped that such observations may be extended with this telescope to 2 billion light years.

The regular galaxies have rotational symmetry. Classified under them are normal and barred spirals (or spiral nebulae) and related to them are the elliptical galaxies.

The normal spirals are characterized by two main whorls, each of which may have several branches, which come out from opposite sides of a large central condensation and wind about this condensation in the same plane and in the same direction. The central condensation is distinctly ellipsoidal in form, being much more extensive perpendicular to the plane of the whorls than are the whorls themselves. The spirals are found in all types of orientation, some with the plane of the spiral perpendicular to the line of light, and in others with the whorls seen edge on. In the latter cases a dark bank is observed passing across the nucleus as though there was a dark extension in the plane of the whorls which would otherwise be unobserved. The barred spirals differ from the normal spirals in that the arms begin at the ends of a long bar which extends outward from the central condensation or nucleus.

Elliptical galaxies show some resemblance to the central regions of spirals. On Hubble's diagram, the sequence of regular galaxies progressed from elliptical systems in a branching sequence to either normal spirals or barred spirals. This sequence has served as a basis for considering the evolution of galaxies.

SPIRAL SCANNING. **Scanning, spiral.**

SPLASH. The incident of impact of a missile with the Earth. It is generally used in connection with descriptions of instrumentation coverage, e.g., *telemetry to splash* would mean that recording of telemeter signals down to actual impact would be desired. The term is derived from the practice of testing large missiles over water.

SPOILER. In aerodynamics, a surface projected into the slipstream around an **airfoil** for the purpose of reducing **lift**.

SPONTANEOUS FISSION. **Fission, nuclear.**

SPOT JAMMING. Jamming, spot.

SPRAY DOME. The mound or column of broken water and spray thrown up over the point of burst of an underwater nuclear explosion by reflection of the blast wave at the surface.

SPURIOUS RADIATION. Any radiation from a transmitter other than that produced by the **carrier** and its normal **sidebands**. A radiated harmonic of the carrier is one example of a spurious radiation.

SPURIOUS RESPONSE. Output from a **receiver** due to a signal or signals having frequencies other than that to which the receiver is tuned.

SPURIOUS SIGNAL. Any unwanted signal, either generated in the equipment itself or having external origin (noise).

SPUTNIK. Around midnight local time on October 4, 1957 mankind's first satellite rocket rose slowly into the sky, from a launching site somewhere north of the Caspian Sea, and gradually arched southward. At 1.46 A.M. Moscow time it passed over the Moscow area, demonstrating that it had indeed begun its historical life which was to last 90 days.

With a weight of 184.3 lb. the satellite was about 9 times heavier than the planned U.S. Vanguard satellite. The launching vehicle must therefore have been significantly larger than the Vanguard vehicle. An indication of the size was given by Moscow with the announcement that the thrust of the first stage was 264,000 lb., and that of the second stage 79,000 lb., while the third stage was designated as having had a small motor of unspecified performance. It was further stated that the first stage had a cut-off velocity of 4,500 mph (6,500 ft/sec) and the second stage 12,000 mph (18,000 ft/sec). If we assume a velocity equivalent for gravitational and drag losses of 2,500 ft/sec for the first stage and 2,000 ft/sec for the second stage (the third stage must have worked practically loss-free, being outside the relevant atmosphere and burning about horizontally), then the ideal velocity increment for the first and the second stage would be 9,000 ft/sec and 13,500 ft/sec, respectively. Both stages probably used liquid oxygen and kerosene as propellants. Their average exhaust velocity must therefore have

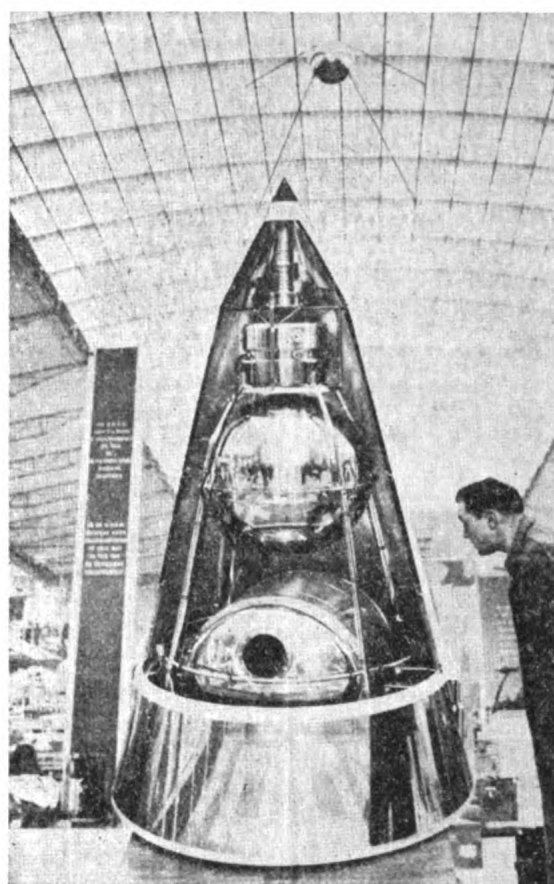
been approximately 8,700 ft/sec and 9,700 ft/sec, respectively, the increase in the second stage being due to a higher nozzle expansion ratio at altitude. Assuming initial thrust-to-weight ratios around 1.5 for both stages, which is characteristic for modern large rocket vehicles, we can deduce that the take-off weight may have been around 180,000 lb (82 metric tons) with a second-stage gross weight (i.e., including the third stage) of the order of 44,000 to 50,000 lb, depending on the performance of the third stage. The mean altitude of the Sputnik I orbit was around 300 nautical miles. The corresponding circular velocity is 24,900 ft/sec (7,600 miles/sec). Neglecting the small contribution from Earth's rotation in this case, it can be assumed that the vehicle had to bring up an orbit injection velocity at the perigee (eccentricity 0.053) of local circular velocity (25,500 ft/sec at 125 nautical miles) multiplied by the square root of $1 + e$, resulting in a cut-off velocity of 26,100 ft/sec (7.96 km/sec). No information appears to have been released on the third stage, so that its quantitative data are speculative over a comparatively wide range. Depending on how one breaks the 44,000 to 50,000 lb., into second and third stages, and what exhaust velocity one assumes for the third stage, this stage may weight less or more than one thousand pounds. Numbers are therefore not too meaningful in this case. Assuming that this stage had a solid propellant system, and equating the Russian state of the art in this field to the U.S.A. level, tentative calculations leave one with the feeling that this vehicle could have carried a heavier payload into orbit than Sputnik I. It is therefore possible the launching of Sputnik I was to a degree a trial shot for the planned launching of the biosatellite Sputnik II, using the same first two stages and a modified (this time perhaps liquid) third stage. This speculation is supported by the fact that the second launching occurred so shortly after the first one, and the surmise that they probably wanted to be particularly sure that the second and more spectacular satellite was not a failure. It is therefore likely that the same two-stage booster system was used for both Sputniks, and that the Sputnik I system did not carry its full orbital payload weight.

The orbits of both Russian satellites are steeply inclined with respect to the equator,

so that little benefit could have been derived from the Earth's rotational speed in view of the fairly high latitude of the Russian launching site. While the orbit of Sputnik I was inclined almost 62 deg., the Sputnik II orbit had an inclination of about 155 deg., that is, the vehicle must have been launched in a southeasterly direction (inclination to the meridional plane is therefore 25 deg.). (For orbital data, see table on Page 541, in article on **satellite, artificial.**)

Sputnik I is a spherical body, equipped with four long whip antennas. The shell is made of aluminum. Most of the weight seems to have been concentrated in batteries. The signal consisted of alternate dash modulations of the two carrier frequencies, and may have transmitted in coded form pressure, temperature and magnetic field data. However, a cut-away view of the satellite, published in the Soviet magazine "Technology for Youth" indicates only a magnetometer. On the other hand, Sputnik II not only carried the dog Laika in its pressurized cabin, together with vital accessories and instrumentation for measuring Laika's pulse, breathing, blood pressure and body temperature, but accommodated also, aside from batteries, a special container with instrumentation to measure internal pressure, temperatures, ultraviolet radiation and cosmic primary radiation. It apparently has never been officially clarified so far, whether the weight of 1,118 lb., represents the total weight delivered into orbit (that is, including the empty third stage), or only the satellite section proper. From optical measurements, the approximate dimensions of the satellite were determined to be some 32 feet in length and around 5 feet in diameter.

Few results have been announced so far from these experiments. It has been stated that not enough information could be obtained about Laika (unfortunately, the transmitters became silent after 5 days, either due to mechanical failure or possibly a meteor hit), and that more animal experiments would be necessary. It was also announced that Laika's heart beat remained on a higher frequency level longer after the ascent (with accompanying high g-load, followed by weightlessness), than when the dog's pulse was measured on Earth following a high-g test in a centrifuge. Another generally observed result of the Sputnik I test is that the air drag (or combined air drag and electrical force drag



Sputnik I (at ceiling) and interior of Sputnik II. The models of the first and the dog-carrying second Russian satellites were shown at the Brussels World Fair. At the bottom of the cone is the pressurized gondola, carrying the dog Laika. Above it are the instrument sphere and batteries. (United Press Photo.)

from numerous ionized particles) at several hundred miles altitude is 3-5 times higher than was deduced formerly from high-altitude sounding tests. Sputnik III launched on May 15, 1958. It appears to be the most complete measuring laboratory in orbit so far.

SQUALL. A sudden, strong wind which may or may not be accompanied by a wind shift. Rain and snow squalls are showers accompanied by strong winds.

SQUALL LINE. Thunderstorms, rain showers or squalls, and snow showers or squalls often appear in a long line sometimes reaching hundreds of miles but only one **squall** in depth. Such lines of squalls normally move perpendicular to their leading edge.

SQUARE-LAW DETECTOR. A vacuum-tube circuit in which the output signal current strength is proportional to the square of the radio-frequency input voltage. The demodulation depends on curvature or non-linearity of the characteristic, rather than on rectification, to produce the distortion or asymmetrical form of the modulated wave necessary for detection. The largest distortion term is the second power, or square term.

SQUARE WAVE. A wave which alternately assumes two fixed values for equal lengths of time, the time of transition being negligible in comparison with the duration of each fixed value. A square wave requires a considerable number of sine-function frequencies to express it in a Fourier series. These components are not mere mathematical fictions but are true electrical components in the case of an electric wave. They may be separated and examined by means of proper filter circuits. Since a square wave will contain a long series of frequencies, it may be used for determining rapidly the frequency response of a piece of equipment by applying the wave to the input and noting the distortion of the output wave. The distortion is due to certain frequencies of the original wave being attenuated or amplified out of proportion in passing through the circuit. Thus the necessity of making a laborious series of tests at various frequencies using sine waves is avoided. When an operator is properly trained in interpreting the results of such testing, it offers a rapid means of checking amplifiers, networks, etc. These square waves may be generated by a variety of electronic circuits.

SQUELCH. To automatically quiet a receiver by reducing its gain in response to a specified characteristic of the input.

SQUELCH CIRCUIT. A circuit used to eliminate unwanted signals, frequently noise.

SQUIB. A small pyrotechnic device, usually electrically detonated, used to ignite rocket motors, initiate explosive bolts, or for other applications where a low order explosion or a simple fire source is desired. Squibs require a fractional ampere current for initiation. Squibs should be made as sensitive as possible to eliminate heavy battery requirements in missiles. This sensitivity makes the squibs dangerous during installation. Extensive wire

harnesses are often attached to squibs, whereby they may pick up enough energy, by electrical or electromagnetic induction, for detonation. Precautions should be taken against nearby electrical circuits or transmitters.

SQUINT ANGLE. A geometrical characteristic of an antenna defined as the angle between the main lobe of the antenna pattern and the spin axis of a gyroscope used to stabilize the antenna.

Sr. Strontium.

SRI. Stanford Research Institute; Stanford, California.

SSB. Space Science Board, a 16-member group established jointly by the National Academy of Sciences and the National Research Council to "survey . . . the problems, implications and opportunities of man's advance into space."

SSIP. Sub-system integration plan.

SSM. Surface-to-surface missile. (See missile, ground-to-ground; missile, guided; model designation.)

SSM-A-12. Lacrosse.

SSM-A-14. Redstone.

SSM-A-17. Corporal.

SSM-A-23. Dart.

SSM-N-2. Triton.

SSM-N-8. Regulus I.

SSM-N-9. Regulus II.

STABILITY. (1) That attribute of a system which enables it to develop restoring forces between the elements thereof equal to or greater than the disturbing forces so as to reestablish a state of equilibrium between the elements. (2) In aerodynamics, the adherence of a missile to its desired attitude during its flight. Stability is most important in vertically launched missiles having slow takeoff accelerations. Early stability is achieved by thrust direction control devices. These may be gimballed motors or jet vanes. Both devices merely deflect the motor's thrust vector. Stability during early flight may be insured

by the use of guiding rails during launch. After the missile achieves speed, its stability can be secured from its aerodynamic design. Spinning the whole configuration about its longitudinal axis is another method. The most common method for stabilizing a missile is by use of the principle of *arrow stability*. In this system the same principle that keeps an arrow headed forward is applied. To do this the center of gravity of the configuration must remain in front of the center of pressure. Arrow stability is achieved by providing enough fin surface at the rear of the missile to produce an aerodynamic force near the tail to prevent it from moving out of line.

STABILITY, ARROW. Stability; weathercock stability.

STABILITY (AND CONTROL) COEFFICIENTS. A set of coefficients which assume linear aerodynamic conditions in the missile equations of motion in a plane of maneuver at a constant speed, and which are useful in defining certain characteristics of a missile, e.g., weathercock frequency, damping, stability and control, etc.

STABILITY, DIRECTIONAL. Stability of a missile with reference to disturbances about its normal axis, i.e., disturbances which tend to cause yaw.

STABILITY DERIVATIVES. Equations of motion for a missile associated with stability and control and based on linear aerodynamic coefficients. The lateral stability derivatives relate to:

Directional stability—yawing motion due to yaw
Rolling moment due to yaw
Damping in yaw
Damping in roll
Rolling moment due to yawing velocity
Yawing moment due to rolling velocity

Similar derivatives exist for the pitch plane.

STABILITY, DYNAMIC. The characteristic motion of a missile as it returns to its steady-state condition after a disturbance has produced an unbalanced moment. The natural frequency of this weathercock oscillation and the time-to-damp-to-half-amplitude are the usual criteria for dynamic stability.

STABILITY, EFFECTIVE STATIC. In aerodynamics, the slope of the moment coefficient versus normal force coefficient curve.

STABILITY, INHERENT. Stability of a missile owing solely to the disposition and arrangement of its fixed parts: i.e., that property which causes it, when disturbed, to return to its normal attitude of flight without the use of the control system or the interposition of any mechanical device.

STABILITY, LATERAL. Stability of a missile with reference to disturbances about its longitudinal axis: i.e., disturbances involving rolling or sideslipping. The term lateral stability is sometimes used to include directional and lateral stability, since these cannot be entirely separated in flight.

STABILITY, LONGITUDINAL. Stability of a missile with reference to disturbances in its plane of symmetry, i.e., disturbances involving pitching and variation of the longitudinal and normal velocities.

STABILITY, STATIC. That property of a missile which causes it, when its state of steady flight is disturbed, to develop forces and moments tending to restore its original condition. The amount of static stability is usually measured in terms of missile body diameters, i.e., so many body diameters (distance) between the center of pressure and the center of gravity.

STABILIZED PLATFORM. A space-fixed reference framework often used to mount guidance **accelerometers** so that they may integrate and thus yield positions and velocities from an unchanging reference plane. A stabilized platform is a basic requirement for an **inertial guidance** system. Two or more gyros (stable elements) are usually used to maintain the attitude of the stabilized platform, one gyro monitoring two degrees of freedom. Small potentiometers detect motions of the gyro gimbals with reference to the stable elements and these detected errors are fed back into the platform's **servo system** to control the attitude of the platform. The space rigidity of the gyros is used as the basis for this control. Once the stabilized platform is established, sensitive accelerometers mounted on it in a predetermined coordinate orientation measure accelerations in each of

the selected coordinate directions. These accelerations are integrated either mechanically or electrically to yield the instantaneous velocities and the distances traveled. These data are then used in the missile computers to determine the time for motor cut-off and path control maneuvers. (See illustration facing Page 219.)

STABILIZER. (1) An airfoil whose primary function is to increase the stability of the airframe. Stabilizers may be horizontal or vertical depending upon their orientation on the airframe. On aircraft when no distinction is made, the term stabilizer conventionally refers to the horizontal stabilizer. (2) A substance added to a solid propellant to retard chemical decomposition during storage.

STABLE ELEMENT (STABLE TABLE; 3-AXIS TABLE; STABLE PLATFORM). A gyroscope-stabilized platform or a stable free gyroscope used as a reference system for guidance and control purposes. (The platform characteristics usually include: minimum deadzone, high gimbal frequency response, good linearity, high signal resolution and large angular range.)

STABLE SERVO. Servo, stable.

STAGE. (1) All the components in a circuit containing one or more vacuum tubes having one single input and one output, the input receiving power from a preceding stage or device, and the output feeding power to a succeeding stage or device. (2) In a missile consisting of several sections which are progressively jettisoned or staged during the flight, the independent sections, when containing a power plant, are termed stages. Note that an unpowered payload (e.g., reentry body) is not classified as a stage.

STAGING. Act of jettisoning, at a predetermined flight time or trajectory point, certain missile components (engines, tanks, boosters, staging equipment and associated equipment) that are no longer needed.

STAGNATION POINT. In aerodynamics, a point at which the moving fluid comes to rest or a zero velocity with respect to the body experiencing the flow. A stagnation point exists wherever a streamline intersects a boundary or another streamline. Theoretically, on an airfoil at supersonic speed two

stagnation points are created, one at the **leading edge** and one at the **trailing edge**.

STAGNATION PRESSURE. The pressure at a stagnation point in the flow. The stagnation pressure is equal to the total of the dynamic pressure (due to movement of the fluid) and the ambient pressure (the local pressure measured by an instrument moving with the fluid). In effectively inviscid and irrotational flow, the Bernoulli theorem shows that the stagnation pressure is equal to the total head, which is everywhere the same.

STAGNATION PRESSURE. The pressure at a stagnation point in the flow. In effectively inviscid and irrotational flow, the Bernoulli theorem shows that the stagnation pressure is equal to the total head which is everywhere the same.

STAGNATION REGION. For high speed missiles, a region at the front of the nose cone where there is negligible velocity of the air flow along the axis; the air is at **stagnation temperature**.

STAGNATION TEMPERATURE. The temperature of air which has been brought to rest from a given velocity or Mach number.

STALLING POINT. The angle-of-attack of an airfoil at which the lift is just insufficient to support the flight of the vehicle, or at which the designed function of the airfoil begins to fail. It is the point at which **burbling** occurs at the **trailing edge** of the wing or fin because the **critical angle of attack** has been exceeded.

STANDARD AIR. (1) (*ASME definition*.) Air at a temperature of 68°F, a pressure of 14.7 psia, and a relative humidity of 35% (0.075 density). (2) (*Aerodynamic standards*.) Air having a temperature of 59°F, a pressure of 14.7 psia (2116.8 psfa), a density of 0.002378 lb-sec²/ft⁴, a kinematic viscosity of 0.0001566 ft²/sec, and a coefficient of viscosity of 37.24×10^{-8} lb-sec/ft².

STANDARD ATMOSPHERE. Atmosphere, standard.

STANDARD CONDITIONS. For a gas, a temperature of 0°C (32°F) and a pressure of 1 standard atmosphere (see **atmosphere, standard** (1)). For a solid element, the allotropic form in which it most commonly occurs,

and at ordinary temperatures, and at one atmosphere pressure.

STANDARD DAY. A day whose temperature and pressure vs altitude characteristics are standardized. A number of standard days are in use: NACA, Navy BuAer, etc.

Polar } Standard days used for design for
Tropical } listing dependent flight conditions.

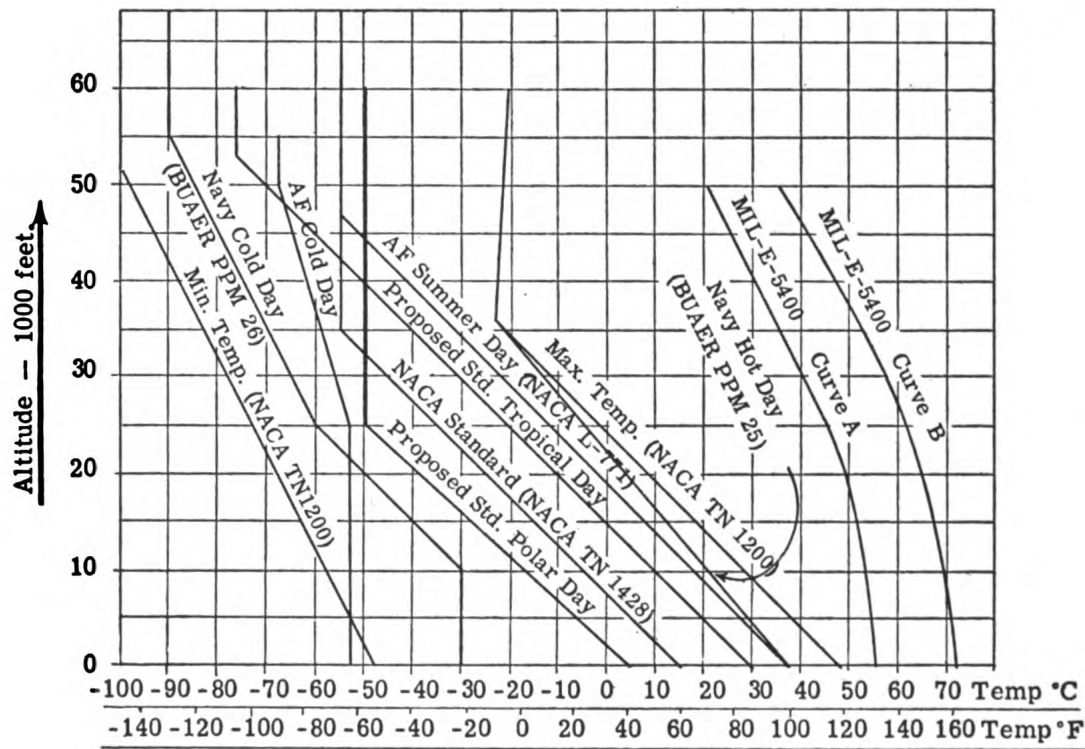
Cold } Standard days used for design
Hot } for non-time dependent conditions.
These characteristics represent statistical envelopes and cannot exist meteorologically.

STANDARD DISPERSION. Standard deviation.

STANDARD ERROR. Standard deviation.

STANDARD SEA WATER CONDITIONS.

For acoustics, "standard sea water conditions" exist with the water at a static pressure of 1 atmosphere, temperature of 15°C and a salinity such that the velocity of sound propagation is exactly 1500 meters per second. Under these conditions the following other properties have been derived from experimental data: salinity, 31.6 parts per thousand; density, 1.02338 grams per cubic centimeter; char-



Characteristics of standard days.

STANDARD DEVIATION. The **root-mean-square** value of the deviations of a series of n like quantities X_j from their mean, \bar{X} . It is given by

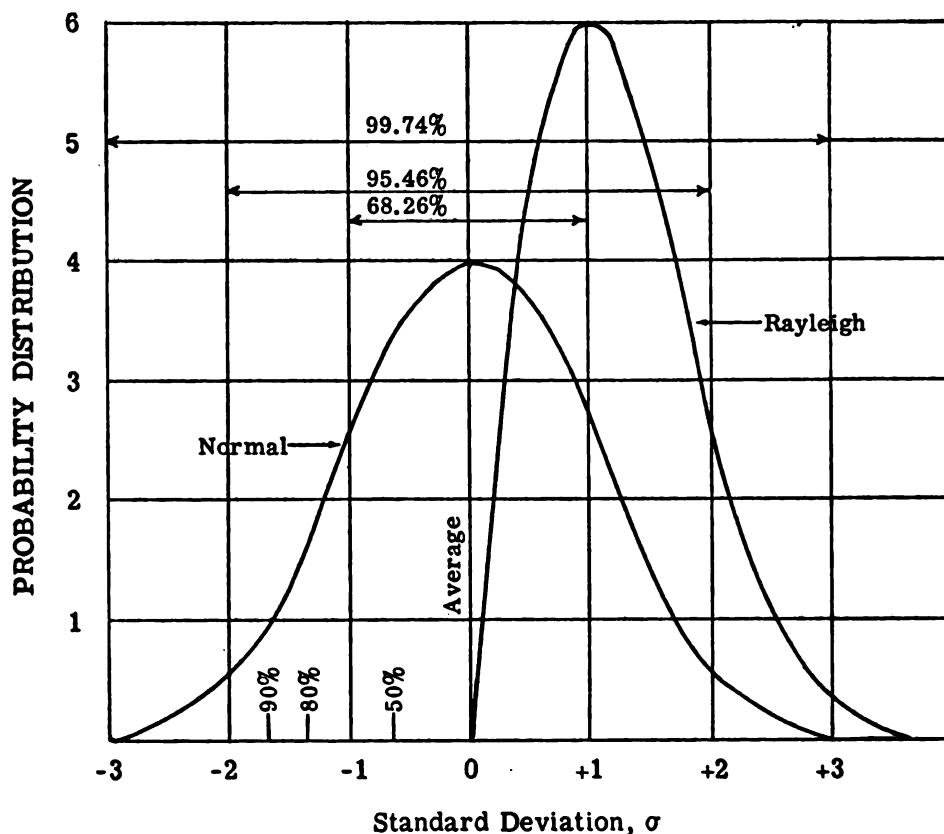
$$\sigma = \left[\frac{\sum_{j=1}^n (x_j - \bar{x})^2}{n} \right]^{1/2}.$$

If the quantities X_j are distributed according to a **Gaussian error function**, the standard deviation bears a simple relationship to the **average deviation** and to the **probable error**. (See Figure on Page 588.)

acteristic acoustic impedance, $c = 1.53507 \times 10^2$ CGS units; pressure spectrum level of thermal noise, 82.17 db below 1 microbar. These standard conditions were chosen to represent the average conditions on continental shelves except tropical waters. The hydrostatic pressure increases the velocity by 0.018 meters per second per meter of depth, and also increases the density by 0.000045 grams per cubic centimeter per meter of depth.

STANDARD TIME. Civil time.

STANDARD TIME ZONES. Time at the 24



Normal frequency curve and Rayleigh distribution.

standard meridians. In the United States and Canada, the standard time zones are the 60th or *Atlantic*, 75th or *Eastern*, 90th or *Central*, 105th or *Mountain*, 120th or *Pacific*, and 135th or *Alaskan*.

STANDARD TRAJECTORY. Trajectory.

STANDING OPERATING PROCEDURE (SOP). A set of instructions covering those features of operations that lend themselves to a definite or standardized procedure without loss of effectiveness. The procedure is applicable unless prescribed otherwise in a particular case. Thus, the flexibility necessary in special situations is retained.

STANDING WAVE. Wave, standing.

STANDING WAVE RATIO (SWR). In a radio frequency transmission line the quantity describing the variation of the rms voltage.

$$swr = \frac{E_{\max}}{E_{\min}}$$

When measurements are made which are pro-

portional to the square of the voltage, the *power standing wave ratio* is obtained.

STANTON NUMBER. Aerodynamic coefficients.

STAR(S). A major celestial object, similar to the sun in its essential characteristics, that is producing internally the energy which it radiates. Stars are classified by size (**stellar magnitude**) by distance (measured when possible by **stellar parallax**) and by spectrum (**spectral classification**). Data on representative stars is given in the Table on Page 589.

STAR BRIGHTNESS MAGNITUDE. A first magnitude star gives about 100 times as much light as a sixth magnitude star. The fifth root of 100 is 2.512, and this is used as the standard magnitude ratio. A first magnitude star is 2.512 times as bright as a second magnitude star, and so on. Since a difference of 0.1 is the smallest change in magnitude that can be detected by the human eye, tabulated magnitudes are usually given to one decimal place. These magnitudes are apparent mag-

PHYSICAL CHARACTERISTICS OF SOME TYPICAL STARS*

STAR	SPECTRAL CLASS	TEMPERATURE IN °K.	DENSITY IN TERMS OF WATER	REFERRED TO SUN AS UNITY		
				Luminosity	Mass	Diameter
GIANTS						
Antares.....	M ₀	3,100	0.0000003	3500	30	480
Aldebaran.....	K ₅	3,300	0.00002	90	4	60
Arcturus.....	K ₀	4,100	0.0003	100	8	30
Capella.....	G ₀	5,500	0.002	150	4.2	12
MAIN SEQUENCE						
β Centauri.....	B ₁	21,000	0.02	3100	25	11
Vega.....	A ₀	11,200	0.1	50	3	2.4
Sirius A.....	A ₀	11,200	0.4	26	2.4	1.8
Altair.....	A ₅	8,600	0.6	9.2	2	1.4
Procyon.....	F ₅	6,500	1.2	5.4	1.1	1.9
α Centauri A.....	G ₀	6,000	1.1	1.12	1.1	1.0
The Sun.....	G ₀	6,000	1.4	1	1	1.0
70 Ophiuchi A.....	K ₀	5,100	0.9	0.42	0.9	1.0
61 Cygni A.....	K ₇	3,800	1.3	0.21	0.5	0.7
Krueger 60A.....	M ₁	3,300	9	0.002	0.3	0.3
WHITE DWARFS						
Sirius B.....	F	7,500	27,000	0.10	0.96	0.034
O ₂ Eridani B.....	A ₀	11,000	64,000	0.003	0.44	0.019

* For a general discussion of Population I and Population II stars, see Giant and Dwarf Stars.

nitudes of brightness in the optical wave length portion of the spectrum.

STAR CATALOGUES. Any listing of stars, usually arranged in order of increasing **right ascension**, is known as a star catalogue. Originally, star catalogues were intended merely for the purpose of providing accurate positions of the stars for use by navigators, but many modern catalogues are designed to provide particular characteristics of the stars.

The oldest existing star catalogue is contained in the *Almagest* of Ptolemy issued about 137 A.D. This is undoubtedly a reissue of the catalogue of Hipparchus of which no copy is known to exist. The *Almagest* catalogue was the only one of any real value until the 15th century when an Arabian catalogue made its appearance. Tycho Brahe's catalogue of 1580 marks the dawn of the modern era of star catalogues and since that time many others have appeared. Probably the most comprehensive catalogue issued is the *Bonner Durchmusterung*, which first appeared about 1850.

Many particular types of catalogues are issued for particular purposes, such as catalogues of **stellar magnitudes**, **spectral class**,

proper motions, **double stars**, **variable stars**, etc.

STAR FINDER. An instrument designed for the purpose of quickly determining the **horizontal coordinates** of a star, at a certain place and time, with an accuracy sufficient to locate it for observational purposes, is known as a star finder. A star finder may also be used for the reverse process of determining the name of an unknown star whose horizontal coordinates have been approximately measured.

Various mechanical types of star finders have been designed and placed on the market. The simplest of these types is a tube mounted in the same manner as an equatorial telescope, but having the altitude of the polar axis easily adjustable for **latitude**. The **declination** circle has the values for the 22 navigator's stars indicated and has the hour circle arranged with various movable dials so that the **hour angle** of any navigator's star may be quickly set for local time in a given longitude. All types of mechanical star finders must be properly oriented and kept level while in use, hence they are far more practical for use on land than on a ship at sea or in the air.

For use on a moving ship several types of star finders have been devised which have a map of the celestial sphere, usually drawn on the stereographic projection, and with a set of transparent disks to be placed over the map. The disks have curves marked on them showing horizontal coordinates and the set covers a wide latitude range. To use such a star finder the disk most nearly corresponding to the latitude of the observer is placed over the star map and oriented in accordance with printed directions. The observer's local time and longitude govern the orientation in most cases. With the disk in proper position the horizontal coordinates of objects on the star map may be immediately determined.

STAR GRAIN. A solid propellant configuration having an internal star-shaped characteristic cross section.

STAR TRACKING (AUTOMATIC CELESTIAL NAVIGATION). A celestial navigation technique used for guiding long-range surface-to-surface missiles. The system consists of a device to measure attitude of the stars, an accurate clock and a storage device to include information on chart and star tables.

STATE. In its fundamental connotation, this term refers to the condition of a substance, as its state of aggregation, which may be solid, liquid, or gaseous—massive or dispersed. As extended to a particle, the state may denote its condition of oxidation, as the state of oxidation of an atom, or the energy level, as the orbital of an electron, or in fact, the energy level of any particle.

STATE, STEADY. Steady state.

STATIC. The name commonly applied to all the various random electrical disturbances which are picked up by a radio receiver. These can be divided into two general classes, natural and man-made static.

STATIC BEHAVIOR. The behavior of a control system, or an individual unit, under fixed conditions (as contrasted to dynamic behavior which refers to behavior under changing conditions).

STATIC FIRING. The firing of a rocket motor or rocket engine in a hold-down posi-

tion to measure thrust and accomplish other tests.

STATIC PRESSURE. The force exerted by a stationary fluid normal to a surface; or by a moving fluid normal to the direction of motion.

STATIC STABILITY. Stability, static.

STATIC TEMPERATURE. In aerodynamics, the temperature as read on a thermometer moving with the air. Its symbol is T_s . It is the actual temperature of a moving gas stream. It is related to total temperature in the same manner that static pressure is related to total pressure. It is measured in such manner that no effect on the measurement is produced by the velocity of the air or gas.

STATIC TEST. (1) A structural test used to establish degree of conformance to the design. (2) See static testing.

STATIC TESTING. The testing of a device in a stationary or held-down position as a means of testing and measuring its dynamic reactions. Said especially of a rocket motor as a means of measuring thrust. This is more properly termed a captive test.

STATIC THRUST. Thrust, static.

STATISTICS. (1) The science of interpreting data for meaningful results. (2) The combination of data obtained from individual events or from separate entries of events. See error and the following entries for the application of statistics to the determination of uncertainties. (3) The distribution laws which result from statistical mechanics.

STATION NUMBER. In locating components on a missile, it is conventional to use a numbering system in which the nose of the missile is designated as the "zero station" and other stations are located at measured distances in inches behind the zero station. For example, Station 300 would be at the section 300 inches to the rear of the nose.

STATIONARY ORBIT. A type of satellite orbit in which the altitude-speed combination is such that the satellite appears to stand still over one locality on the Earth's surface. It is the same as a "24-hour orbit," that is it

revolves about the Earth in consonance with the Earth's period of rotation.

STATOR. The stationary portion of a dynamo.

STATOSCOPE. A sensitive barometer used in aerial photography for measuring small differences in altitude between successive air stations.

STAY TIME. In liquid rocket engine usage, the average length of the time spent by each gas molecule or atom within the chamber volume.

STEADY STATE. (1) A physical system is said to be in a steady state if the various quantities describing the system are either independent of time or are periodic functions of time. Thus an alternating current circuit is in a steady state after all transient effects of a disturbance have disappeared. (2) A condition of dynamic balance in combustion, as in an equilibrium reaction, where the concentration of each of the reactants remains constant. In such cases the loss of reactants to form products just balances the formation of reactants from the products in the reverse reaction. (3) In aerodynamics, the state of static stability of the missile; no transients are present.

STEADY-STATE OSCILLATION. A condition in a dynamic system in which the energy input and damping are so in balance that the oscillation neither diverges nor damps out.

STEADY-STATE VIBRATION. Oscillation, steady-state.

STEERABLE ANTENNA. Antenna, steerable.

STEFAN-BOLTZMAN LAW. The total radiation from a black body or complete radiator is given by

$$E = \sigma T^4$$

where T is the absolute temperature and $\sigma = 5.672 \times 10^{-5}$ erg cm⁻² deg⁻⁴ sec⁻¹. Sometimes called the "Fourth Power Law."

STELLAR ENERGY. The source of the energy radiated by the stars is discussed briefly in the last portion of the article on the sun.

STELLAR INTERFEROMETER. An attachment for astronomical telescopes by which Michelson was first able to measure the angular diameters of certain stars. (See Interferometer.)

STELLAR MAGNITUDE. In the first star catalogues issued by Hipparchus and Ptolemy the relative apparent brightness of the stars was designated by a system of six numbers referred to as the magnitudes of the stars. Twenty of the brightest stars were referred to as first magnitude, while those at the limit of visibility were called sixth magnitude. The stars with brightness intermediate between the two extremes were assigned to a magnitude number with the numbers increasing with faintness of the stars. With the application of the telescope to astronomy many faint stars were discovered and the need for additional magnitude numbers became evident. Unfortunately for modern astronomers, the attempt was made to amplify the ancient magnitude system not only to include the fainter stars, but also to indicate finer gradations of brightness by a decimal system. The result is that astronomers are now using a system which was started about 2000 years ago and has all of the clumsiness and inconvenience for modern observers which is characteristic of so many of the ancient scientific instruments.

There is no definite evidence that Hipparchus or Ptolemy had any idea in mind at the time they first used the magnitude system other than to provide a rough descriptive term for the stars. In the early part of the 19th century Sir John Herschel found that the apparent brightness of a first magnitude star is about 100 times that of a sixth magnitude. In 1850 Pogson proposed a fixed scale of stellar magnitudes based upon the original scale of Hipparchus and Ptolemy, but so adjusted that it would agree at the sixth magnitude with the system employed by Argelander in his famous Bonner Durchmusterung. Adopting the announcement of Herschel that the ratio of brightness of a first and sixth magnitude star is approximately 100, Pogson proposed that the ratio between successive magnitudes should be $\sqrt[5]{100}$ or approximately 2.512. This leads to an analytical expression for the magnitude scale as follows:

Call B_1 the apparent brightness of a star of magnitude H and B_2 the apparent brightness

of a star of magnitude J , then $B_1/B_2 = 2.512^{(J-H)}$ or, expressed in logarithmic form, $\log_{10} B_1 - \log_{10} B_2 = 0.4(J-H)$.

Since the magnitude scale is a scale of relative brightness, it is necessary to establish a system of standards. For this purpose a group of stars in the immediate vicinity of the north celestial pole has been selected. The magnitudes of the stars in this "north polar sequence" have been very carefully determined and agreed upon by the International Astronomical Union. All magnitudes determined at the present time should be referred, either directly or indirectly, to this standard sequence.

The magnitude scale as originally established referred to the relative apparent visual brightness of the stars. With the application of photography to astronomy difficulty with the magnitude scale immediately became evident. If we have two stars of the same visual magnitude, one of them blue and the other red, the photographic image of the blue star will be much stronger than the photographic image of the red star. The colors of the stars in the sky vary with the different spectral types, and the visual magnitude differences between a number of stars of different spectral types will differ considerably from the magnitude differences obtained by photographic means. Furthermore, the photographic magnitudes, so-called, will be different, depending upon the type of plate used and the characteristics of different telescopes, and it becomes necessary to be very explicit in defining the particular range of wavelengths of **spectral** energy that are to be used in any magnitude scale. The difference between the photographic and visual magnitude of a star is known as the color index of the star, the term arising from the fact that the color is the determining factor in the magnitude scale difference.

With the application of various other types of radiation measuring instruments, such as **bolometers** and **radiometers**, to the measurement of the apparent brightnesses of the stars, the necessity has arisen for various different magnitude scales such as bolometric magnitude, radiometric magnitude, etc. The problem of the intercorrelation of the different systems is at present in a very confused state and much research is being carried on in this important field. It is devoutly to be hoped for that in the future some system of express-

ing the apparent brightnesses of the stars may be devised that will replace the present complicated inverse logarithmic scale of magnitudes.

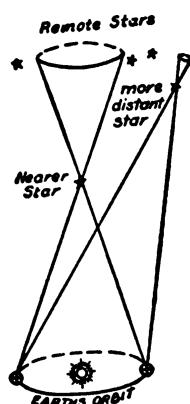
For the purpose of expressing the intrinsic brightness of a star, independent of the distance of the star from the earth, a system of absolute magnitudes has been devised.

STELLAR PARALLAX. The term stellar parallax is used by astronomers as a means for expressing the distance of a given star. Technically defined, stellar parallax is the angle that would be subtended by the mean distance of the earth from the sun (one **astronomical unit**) at the distance of the star from the sun.

From the earliest days of the Pythagoreans any theory of the structure of the **universe** which postulated that the earth might move about the sun was objected to on the ground that such motion should produce an apparent motion of the stars. Copernicus, in proposing his heliocentric theory, met this objection by postulating that the distances of the stars were so incomparably greater than the distance of the earth from the sun that no instrumental methods would be capable of detecting the motion even if it did exist. The attempts to test the Copernican doctrine by searching for this so-called stellar parallax gave a tremendous impetus to the design of accurate instruments, but even with the improvement in instrumental equipment the effect was not observed and the Copernican theory lost ground. It was not until 1838 that **Bessel** was able to definitely prove that the effect is present.

The type of effect to be looked for is illustrated in the figure. The type of curve which the stars should apparently follow due to the earth's motion about the sun varies from an ellipse with eccentricity equal to that of the earth's orbit for stars at the pole of the ecliptic, to oscillations back and forth along a straight line for stars in the plane of the ecliptic.

The problem of determination of stellar parallax is theoretically very simple. All that is necessary is to make a series of observations of the positions of a star on any system of spherical coordinates (e.g., **right ascension** and **declination**) and from the observed changes in position throughout the year determine the stellar parallax. This so-called



Parallaxes of the stars. Owing to the earth's revolution the nearer stars describe parallax orbits annually with respect to the remote stars.

absolute method was attempted many times but failed to reveal any definite value because of the fact that the instrumental corrections were larger than the effect sought for. This is not surprising when we consider that the largest stellar parallax which has ever been found (for the star Proxima Centauri) has a value of $0''.783$, or equivalent to the angle subtended by a ten cent piece at a distance of approximately 3 miles.

With the failure of the absolute method to yield values for the parallaxes of the stars, Bessel and Struve decided upon an indirect or relative method for determining the desired quantity. This method is based upon the assumption that certain stars are at such a great distance that their parallaxes are too small for detection, but that there are other stars closer to the sun which should show motion relative to the distant background. Bessel selected the star 61 Cygni, which was assumed to be relatively close to the earth from a large **proper motion**, while Struve selected the star Vega which has an appreciable proper motion and is also so bright as to imply closeness to the earth. Proceeding by different methods, in 1838 both Bessel and Struve were able to show that the stars which they had selected showed parallactic motion relative to the background of stars.

Until the application of photography to astronomy the problem of determination of stellar parallaxes was very tedious and laborious and up to 1880 distances of less than 25 stars had been determined. With the application of photography the progress of parallax determination became very much more rapid, and at present many long programs of obser-

vations both in the northern and southern hemisphere are nearing completion.

The photographic method consists in first selecting stars which are suspected, either from proper motion, **spectral type**, or other characteristics, to be relatively close to the sun. Plates are taken of these stars, great care being exercised in the guiding, and the brightness of the "parallax star" is reduced until its photographic image compares favorably with the images of the fainter "background stars." The plates are all taken at the same **hour angle**, either east or west, to eliminate so far as possible atmospheric effects, and the dates on which the plates are taken are separated as much as possible to make the effect of the earth's motion as large as possible. Twenty or thirty plates, extending over several years, are taken and the position of the parallax star carefully measured with reference to half a dozen background stars. A least squares solution will yield the motion of the star relative to the background. This motion will consist both of the proper motion and the parallactic shift. The former may be separated from the latter because proper motion is linear in character while the parallactic shift is periodic. For stars within 5 million times the sun's distance from the earth (parallax $0''.04$) the mean of two or three determinations will be correct within 20%. For twice this distance the results are only accurate enough for statistical purposes, while beyond this distance the trigonometric method is practically valueless. Occasionally, due to an unfortunate choice of parallax star or of comparison stars, the value of the stellar parallax comes out to be a negative quantity. Such a "negative parallax" simply means that the star under observation is more distant than those selected for comparison purposes.

STELLAR PHOTOMETRY. The problem of determining the **stellar magnitude**, or brightness, of a star is known as stellar photometry. Since the magnitude scale is a purely arbitrary one, all methods of stellar photometry consist fundamentally in the comparison of the brightness of one star with the brightness of a star of standard magnitude. The simplest method is to make direct visual comparison between the two stars and estimate directly the difference in magnitude. In the so-called "Argelander method" two stars of standard brightness are selected, one brighter and the

other fainter than the star under consideration. The difference in magnitude between these "comparison stars" should not be greater than one magnitude. The observer then mentally divides the magnitude difference between the comparison stars into, say, ten, light steps and estimates the brightness of the unknown star in terms of these steps.

STEP FUNCTION. In mathematics, electronics, or other physical applications, a sudden rise in a quantity such that its value increases or decreases from one level to another very nearly instantaneously.

STEP PRINCIPLE. In rocketry, the procedure of employing one rocket on top of another, each burning in sequence so that when the first burns out, it drops off leaving the remaining rocket(s) with a burn-out velocity. The second rocket then fires, adding its velocity and then drops off. The sequence then continues until the payload achieves its final velocity. This is, in reality, an energy saving scheme in which the dead weight to be accelerated is minimized.

STEP ROCKET. A rocket missile using the step principle. The **Bumper** missile (V-2 with **WAC Corporal** on top) was an American post-World War II application of the step principle. The **Vanguard** Project (Earth Satellite) missile used a 3-stage step rocket.

STERADIAN. A unit solid angle, which encloses a surface on a sphere equivalent to the square of its radius. The total solid angle about a point equals 4π steradians since the area of a sphere of unit radius equals 4π .

STEREOGRAPHIC PROJECTION. In cartography, a technique for portraying the earth's surfaces; the projecting plane is perpendicular to the axis of the earth and points on the earth are projected by straight lines from the opposite pole.

STICTION. *Static friction.*

STIFFNESS. In general the ability of a system to resist a prescribed deviation. In the case of a deformable elastic medium, stiffness is the ratio of a steady force to the elastic displacement produced by it, e.g., for a spring the force required to produce unit stretch. The term is applied most often to an elastic system vibrating about a position of

equilibrium. Acoustic stiffness is the quantity which, when divided by 2π times the frequency, gives the acoustic reactance associated with the potential energy of the medium or its boundaries. The unit commonly used is dyne/cm. Mechanical stiffness is expressed in terms of the various elastic moduli.

STIFFNESS/WEIGHT RATIO. The ratio of the modulus of elasticity to the weight.

STILB. A unit of brightness of a surface equal to 1 candle/cm².

STING. A rod-type mounting attached to a wind tunnel model and extending backward from it. The sting is used to fix the model within the wind tunnel test section and provide outlets for the pick-ups on the model. It is also called stang.

STOCHASTIC VARIABLE. In the mathematics of measurement the stochastic variable is dependent on the random variable, e.g., a random choice of ξ will define some value of X . The stochastic variable is usually the quantity measured experimentally.

STOICHIOMETRIC (MIXTURE). A mixture of the components involved in reaction in exactly the quantities needed for reaction without an excess of any component. It is the ratio of oxidizer to fuel at which there would be no fuel or oxygen left after completion of the process.

STOKE. The cgs unit of kinematic viscosity. It is 1 cm² per sec.

STOL. A type of aircraft having a slow take-off and landing.

STOOGE. A British surface-launched research missile produced by the Fairey Aviation Company. It weighed 738 pounds carrying a 220-pound payload. Its overall length was 7½ feet and its diameter, 12½ inches. It had a 7 foot wing span in a monoplane configuration. The missile was propelled with a solid propellant motor and was launched from a 10-foot ramp with a booster assist. Four AA-type 3-inch rockets were used for boosters. Maximum velocity was 510 feet per second.

STORABLE PROPELLANTS. Liquid missile propellants which can be contained at standard temperature and pressure for pro-

longed periods without spoilage, evaporation or danger.

STORAGE. A missile environmental phase starting with delivery to a depot or other permanent storage area and ending with movement to a dock for transportation. Preventive maintenance is minimized during this period by protective design.

STORAGE, READY. Ready storage.

STOWAGE. A missile environmental phase covering its temporary storage, usually aboard a ship. Stowage is ordinarily and arbitrarily considered not to exceed a 6 month period.

STRAIN. The deformation of a body resulting from a stress; measured by the ratio of the change to the total value of the dimension in which the change occurred.

STRAP. (1) In magnetrons, the link connecting alternate resonator segments. (See **magnetron, strapping.**) (2) A metallic band encircling a structure to strengthen it or to join two or more of its components.

STRAPPING. The process of connecting alternate segments of a magnetron anode together; this prevents jumping from one mode to another, and insures oscillation at a single frequency.

STRATEGIC ATTACK. An attack by means of long-range guided or ballistic missiles (together with long-range bombers or aircraft serving as launch platforms for air-to-surface missiles) directed at selected vital targets of an enemy nation so as to destroy its war-making capacity or its will to fight.

STRATEGIC INFORMATION. Unclassified scientific, technical, industrial or economic (non-statistical) information, the indiscriminate distribution of which may be inimical to the defense interests of the United States.

STRATEGIC MISSILE (SM). A missile carrying a nuclear warhead used for long-range bombardment.

STRATEGIC MISSILE SQUADRON. The smallest Air Force strategic missile organization possessing an administrative capability. It consists of from three to six flights and appropriate command and administrative elements.

STRATEGIC MISSILE SUPPORT SQUADRON. An Air Force organization assigned to the support base. It provides support for all missile units in the launch base area.

STRATEGIC MISSILE WING. An Air Force organization composed of one Strategic Missile Support Squadron and two or more Strategic Missile Squadrons.

STRATEGY. The art of utilizing national resources for best prosecution of a war; pertains to the preparations for battles or campaigns and the exploitation of their outcome.

STRATOPAUSE. The theoretical dividing line between the stratosphere and ionosphere. It is named from analogy with the tropopause (the dividing line between the troposphere and the stratosphere). (See also **atmosphere** and **lapse rate.**)

STRATOSPHERE. That layer of the atmosphere beginning at the tropopause and extending from approximately 10 miles to 20 miles altitude. The stratosphere is between the troposphere and the mesosphere.

STREAMLINE. A continuous line whose tangent points into the direction of the velocity vector at every point of the fluid. Thus, a streamline is always parallel to the local direction of flow, as expressed by

$$\frac{dx}{u} = \frac{dy}{v} = \frac{dz}{w}$$

where dx , dy , dz are the components along the three axes of the line element dl , and u , v , w are the components of the flow velocity. In steady flow, the streamlines are identical with the paths of fluid particles. In two-dimensional flow, the streamlines are lines of constant stream function.

If the streamlines follow closely the contours of a solid body placed in a moving fluid, the drag is usually low and the body is said to be of streamline form.

STREAM THRUST. The sum of the aerodynamic pressure force transmitted across a specified cross section and the time rate of momentum flow across the same cross section.

STREAM TUBE. A tubular space, enclosed by streamlines. A stream tube is generated by the streamlines passing through every point on a closed contour. By definition of a

streamline, there is no flow out of a stream tube except through its ends, and in steady flow the mass flow across any section is constant.

STRENGTH-WEIGHT CRITERION. A design criterion which gives the lightest weight member for a given geometry and loading condition: e.g., in high-temperature applications, a material based on a strength-weight-temperature criterion.

STRESS. The force acting on a unit area in a solid, as in the theory of elasticity. In general, the stress has nine components, X_x , X_y , X_z , Y_x , Y_y , Y_z , etc., defined so that, e.g., X_y represents the force in the x direction acting on unit area of a plane whose normal is in the y direction. However, for equilibrium it is necessary that $Y_x = X_y$, $Z_x = X_z$ and $X_y = Y_x$. The component of a stress which acts at right angles to a surface is known as the normal stress. If this stress is produced by a load whose resultant passes through the center of gravity of the area, it is called an axial or direct stress and is always uniformly distributed over the area. A normal resultant force which causes the fibers to increase in length is a tensile stress, while one which shortens the fibers is a compressive stress. The latter is often called a bearing stress. The component of any stress which lies in the plane of the area is a shearing stress.

STRESS ANALYSIS REPORT. A standard report used in missile design. It includes shear and moment diagrams based on loading conditions presented in the Loads Report, design criteria, design allowables, margins of safety, detail stress analysis and temperature corrections.

STRIP CHART RECORDER. A device which indicates and records any slowly-varying function in real time. Its typical frequency response is less than 50 cycles per second.

STROBOSCOPE. An instrument for viewing moving objects so that they appear stationary. A common type uses a rapidly flashing light, of adjustable frequency. Human persistence of vision causes a vibratory body so illuminated at its frequency to appear stationary.

STRONTIUM. Metallic element. Symbol Sr. Atomic number 38.

STROUHAL NUMBER. A dimensionless parameter relating frequency of shedding of vortices to the wind velocity and characteristic dimension,

$$\text{Strouhal Number} = \frac{\omega d}{2\pi V},$$

where ω is the frequency of vortex shedding in radians per second, d is the diameter of the missile or structure in feet and V is the velocity of air flow in feet per second.

STRUCTURAL DENSITY. The weight of a structural material relative to its enclosed volume.

STRUCTURAL LOADS. Aerodynamic loads, modified by the inertia loads of a missile's component parts during steady-state or dynamic conditions.

STRUCTURAL TEST REPORT. A standard report used in missile design. It includes detail test procedures, loads and load distribution for the static and dynamic tests to be performed to confirm the basic design, and detail test results.

STRUCTURE. The grouping of the various parts of an assembled entity, and the points at which, or the means by which, they are held together.

SUB-ASSEMBLY. In U.S. Air Force terminology, an article replaceable as a whole, consisting of a combination of detail parts having a common mounting, or mounted on each other. Examples are switches, I-F transformers and auxiliary power generators.

SUBASTRAL. Directly beneath a stellar body (on the earth).

SUBCARRIER FREQUENCY. In telemetry, a frequency carrying bits of information; it is one of several frequencies making up the composite modulation signal.

SUBCRITICAL OPERATION. A condition of ramjet operation; if the flight Mach number M_0 decreases during subcritical operation, more air is "spilled over" the intake because of the decreased pressure rise achievable by the diffusion system. As a consequence, the gross thrust decreases still more and if the decrease in Mach number cannot be halted, the ramjet engine finally becomes unable to overcome the drag of the missile it is propelling.

SUBHARMONIC. A component of a periodic quantity having a frequency which is an integral submultiple of the basic frequency. The term subharmonic is generally applied in the case of a driven system whose vibration has frequency components of lower frequency than the driving frequency.

SUBLIMATION. The transformation of a solid directly to the gaseous condition without passing through the liquid state. When the vapor pressure of a solid becomes greater than the atmospheric pressure the solid vaporizes completely at constant pressure. The temperature at the point where the vapor pressure of a solid equals the atmospheric pressure is its sublimation temperature.

SUBMINIATURIZATION. Usually applied to airborne equipment; a technique of reducing size and weight. The next reduction after **miniaturization**. Typical characteristics of subminiaturized packages: high density, special heat dissipation provisions, plug-in design, modularized, printed circuitry, detail attention to layout.

SUB-MISSILE. One of several smaller missiles carried and released by a larger missile; especially in a warhead.

SUBROC. A U.S. Navy submarine launched rocket designed for underwater-to-air-to-underwater (UAUM), trajectories.

SUBSATELLITE. An object designed to be carried into orbit inside an artificial earth satellite but later ejected to serve a particular purpose.

SUBSONIC. Sonic, Sub-

SUBSONIC DIFFUSER. Diffuser, Subsonic.

SUBSONIC LEADING EDGE. A condition of supersonic flow over an airfoil wherein the **leading edge angle**, as measured from the centerline, is less than that of the **Mach angle** μ , defined as:

$$\mu = \sin^{-1} (1/M)$$

the leading edge is said to lie within or behind the Mach angle.

SUBSONIC NOZZLE. Nozzle, subsonic.

SUBSONIC REGION. A region in which the fluid flow is subsonic in contrast with super-

sonic: e.g., where the flow with respect to the surface of a nose cone is subsonic.

SUBSONIC TRAILING EDGE. A condition of supersonic flow over an airfoil wherein the angle between the **trailing edge** and the centerline is less than that of the **Mach angle**.

SUBSTELLAR POINT. A point on the earth directly beneath a given star or planet.

SUBSTRATOSPHERE. A region of indefinite lower limit just below the stratosphere. The substratosphere is not a recognized region of the atmosphere in scientific contexts. The term is used only informally, as "The airliners cruise through the substratosphere at 300 miles an hour."

SUB-SURFACE LAUNCH STRUCTURE. An underground launcher.

SUBSYSTEM. A major functional assembly within a system.

SUBSYSTEM, MAJOR. Large functional division of a weapon system, e.g., airframe, propulsion, guidance, and range safety.

SULFUR. Chemical element. Symbol S. Atomic number 16.

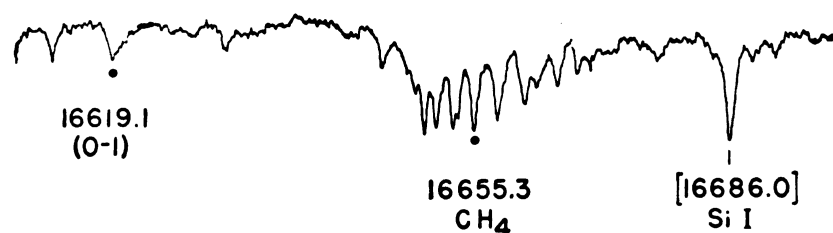
SUM (SURFACE-TO-UNDERWATER MISSILE). Missile, ground-to-ground; model designation.

SUN. The sun is without question the most important of all of the celestial objects, not only to the earth, but also to all other members of the **solar system**. Whatever life exists on the earth, or elsewhere in the solar system, is absolutely dependent upon the **radiation** from the sun for its existence. All forms of energy used on earth for power production, except **nuclear energy**, come from the sun, either by its present radiations, as in the case of water power or wind power, or from its radiations in the past, as in the case of coal or oil. Even the tidal energy, which comes principally from the moon, is influenced to a considerable extent by the position of the sun relative to the moon. From the purely scientific point of view, the sun is of tremendous importance to the astronomer, since it is a typical **dwarf star** of the **G₀ spectral class**, and is close enough to the earth to permit of careful analysis.

Somewhat detailed descriptions of the different portions of the sun and its surrounding atmosphere will be found in articles on the **photosphere**, the **reversing layer**, **chromosphere**, **corona**, **prominences**, and **sun spots**. The mean distance of the sun, as determined

adequate explanation for the differing rotation periods, even for a gaseous object. The sun's equator is inclined to the plane of the ecliptic by $7^{\circ} 10' 5''$.

Observations of the continuous spectrum from the sun and the application of the laws



A portion of the solar spectrum in the infrared. The silicon line at 16686.0 (angstroms) originates in the sun's atmosphere but the methane (CH_4) band is produced in the earth's atmosphere. (Tracing with lead sulfide cell at the Observatory, University of Michigan.)

from many measurements of **solar parallax**, is 149,490,000 kilometers, or 92,900,000 miles. The mean diameter is 1,390,400 kilometers, or 864,000 miles—about 109.1 times the diameter of the earth. Since volume is proportional to the cube of the diameter, we find that the volume of the sun is 1,300,000 times that of the earth. In order to get some concept of these sizes and distances consider the sun as a globe $2'$ in diameter; the earth on this same scale would be a sphere only $0.22''$ in diameter, and would be distant from the sun $215'$. On this same scale the nearest **star** would be 11,000 miles away! The mass of the sun may be determined from the gravitational attraction which it exerts upon the earth and is found to be 331,950 times that of the earth, or 1.982×10^{33} grams (or 2×10^{27} tons). From the mass and the volume the mean density of the sun is found to be about $\frac{1}{4}$ that of the earth, or 1.4 times that of water. The gravitational force on the surface of the photosphere is 27.6 times that on the earth, which is equivalent to saying that a person weighing 100 lbs. on the earth would weigh nearly $1\frac{1}{2}$ tons on the sun.

From a large number of observations of sun spots and also by spectroscopic observations the rotation period of the sun has been found to be different at different distances from the sun's equator. At the equator the sidereal period of rotation is about 24.65 days; in latitude 30° , 25.85 days; in latitude 60° , 30.93 days; and at the poles about 34 days. Such a varying rotation period indicates certainly that the sun is not a solid, but there is no

of radiation indicate that the effective temperature of the surface of the sun is about 5750°K . From the value of the **solar constant** we calculate the rate of radiation from the surface of the sun as 89,500 calories per sq. cm. per min., equivalent to about 84,000 hp. per sq. meter. Residents of northern climates will appreciate this amount of energy better when they realize that it would melt a sheet of ice $40'$ thick in about 1 minute! The problem of the source of this tremendous amount of energy has been the subject of many studies. Taking to account spectroscopic evidence of the composition of the sun, observations of its surface temperature, calculations of its interior temperatures and pressures, and the great amount of energy radiated, the conclusion seems warranted that only **nuclear reactions**, and specifically reactions involving **protons**, can be the source of the energy radiated by the sun and most stars. The physicist Hans G. Bethe, of Cornell University, and the German physicist C. F. von Weizsäcker considered in this connection all known nuclear reactions involving protons. While the light elements **lithium**, **beryllium**, and **boron** react rapidly enough with protons to yield considerable energy, and might be the source of the energy of such young stars as the red **giants**, these elements (i.e., lithium, beryllium and boron) are not present in sufficient quantity in older stars such as our sun, to furnish the energy evolved. The only known reactions which seem to explain their energetics are those involving protons only. There are known two such re-

actions which appear probable as the sources of the energy. They are the **proton-proton chain** and the **carbon cycle**. As can be seen by reference to those entries, both these reactions are **fusion** reactions and both these reactions result in the formation of helium nuclei from protons. Which of these two reactions furnishes the major part of the energy in a given star depends upon conditions of temperature and density, and the observed abundances of nitrogen and carbon. From such considerations, it has been concluded that the carbon cycle yields nuclear energy at a rate corresponding to that in the main sequence stars (see **giant and dwarf stars**) much brighter than the sun, while for main sequence stars fainter than the sun, the proton-proton chain yields the calculated amount of energy. The carbon cycle can operate at the high central temperatures of the bright main sequence stars and the sun, in which both reactions are probably prominent. It is to be emphasized that the foregoing considerations are not final, nor are they the whole story. They do not, for example, include the nucleogenesis of the elements heavier than boron. Dr. E. E. Salpeter has explained a nuclear process in which helium may be converted to heavier elements at very high temperatures with release of further energy.

SUN COMPASS. A type of **astrocompass** with which direction is determined by utilizing the direction of the sun.

SUN FOLLOWER. A system of photoelectric cells with an associated **servo** system to cause a device, e.g., the nose of a rocket, to maintain an orientation facing the sun. Such instruments have been carried by U.S. rocket flights of the **V-2**, **Aerobee** and **Viking**.

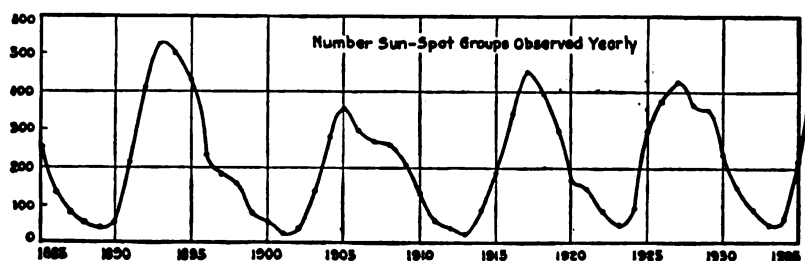
SUNLINE. A line of position derived from a sextant observation of the sun.

SUNSPOTS. As the term implies, sunspots are spots on the surface of the sun which make their appearance on the **photosphere**. There is no record of when these phenomena were first observed. Frequently, they are so large as to be seen with the unaided eye when the brilliancy of the sun is cut down either by thin clouds or by darkened glass. There are Chinese records of sunspots long prior to the early part of the seventeenth century, when Galileo first observed them through his telescope.

In the first place, it must be clearly understood that sunspots are not really dark. They are merely darker than the surrounding regions of the photosphere, and, if the brilliant photosphere were not present, the sunspots themselves would appear intensely brilliant. A typical sunspot has a dark irregularly shaped central portion known as the **umbra**, surrounded by a lighter region known as the **penumbra**. Because of the distance of the sun, the smallest sunspots which can be studied must be at least 150 miles in diameter. Spots with diameters of 40,000 to 50,000 miles are quite common, and instances have been recorded where a number of spots were so close together that the penumbra blended into one area nearly 150,000 miles across.

Sunspots are usually relatively short-lived. About a quarter of them last but a single day, and as many again from 2-4 days. In a few cases large spots have persisted for over a month, the longest case on record being a large group of spots which lasted for nearly 18 months.

Sunspots confine themselves almost exclusively to the solar latitude zones between 5° and 40° north and south of the solar equator. The total number of spots on the surface of the sun varies, with a somewhat regular periodicity of approximately 11 years. The accompanying figure shows the total number



The sunspot number cycle. The point for each year represents the number of sunspot groups observed during that year. The curve shows the roughly periodic variation in the numbers. (From data by S. B. Nicholson.)

of spots observed during each single year from 1885 to 1936. It will be noted that the shape of the curve and the interval between maxima and minima is not the same for each cycle. Along with the variation in number of sunspots there goes a shift in the average location of the spots. At the beginning of a cycle the spots are located at the outer regions of the latitude zones, i.e., between 30° and 40° solar latitude. As the number increases the maximum number of spots is located in about 16° latitude, and by the end of the cycle the spots are about 5° from the solar equator. The beginning of the new cycle is heralded by the appearance of a few spots at considerable distance out from the equator.

Many attempts have been made during the last two centuries to correlate terrestrial phenomena with the number of spots on the surface of the sun. The correlation between sunspot number and electromagnetic phenomena on the earth is positive, and we find that at times of sunspot maximum magnetic storms, with the accompanying shifts in compass variation, and interference with radio and telegraphic communication, are most prevalent. Maximum and minimum auroral displays follow slightly after times of maximum and minimum sunspots. The correlation between solar disturbances and whether conditions on the earth is both weak and puzzling. It has been shown that the solar constant varies with sunspot number, being a maximum when the number of spots is greatest. However, there is definite evidence that the temperature of the air at the earth's surface is lower at the times of sunspot maximum. Studies of the width of tree rings, made by Douglass in Arizona, indicate direct correlation between the periods of wide rings and the sunspot periodicity.

Sunspots are observed to have a distinctly whirling character, not unlike cyclonic storms in the atmosphere of the earth. They are distinctly **magnetic** in character, spots in which the whirling motion is in one direction, all having one magnetic polarity, while spots whirling in the opposite direction will have the opposite magnetic polarity. When two spots are observed relatively close together, as is frequently the case, the two are whirling in opposite directions, and hence have opposite magnetic polarity.

It is believed that sunspots are caused by a whirling mass of gas just below the surface

of the photosphere. Hot gases are brought up until they break through the photosphere, where the sudden reduction in pressure causes them to cool and spread out over the surface, causing a relative darkening. The influence of spots is felt clear out through the atmosphere of the sun, for at the time of sunspot maximum there is also a maximum number of **prominences**. The shape of the solar **corona** is also influenced by the number of spots on the surface of the sun. In spite of the tremendous amount of attention that sunspots have received, there is no adequate explanation as to their origin.

SUPERAERODYNAMICS. The study of the dynamics of gases at very high altitudes or extremely low densities.

SUPERCHARGER. A mechanical pump which forces air into aircraft or its engines for better performance, especially at high altitude. An *internal supercharger* is installed between the carburetor and the cylinders and compresses the fuel-air mixture. An *external supercharger* is located before the carburetor, and blows air into it before fuel is added.

SUPERCOMPRESSIBILITY FACTOR. The ratio of the theoretical density ρ_t to the actual density ρ of a gas. It is abbreviated z . $z = \rho_t / \rho$.

SUPERCONDUCTIVITY. At very low temperatures, within a few degrees of absolute zero, certain metals, alloys, and compounds go through a superconducting transition into a state in which the electrical resistance has a value of zero. The critical temperature of the superconductor and the critical magnetic field curve characterize the material. Persistent electric currents may be induced in a superconducting ring, and show no signs of decay.

SUPERCritical OPERATION. A condition of ramjet operation wherein the heat released by the burner causes the back pressure on the exit section of the diffuser to become too small for maintaining the normal shock at the inlet. The excess pressure (or energy) in the air must be dissipated within the diffusion system by some form of discontinuous process, and such a process is possible only in a supersonic flow. Consequently, the air flows into the subsonic diffuser with supersonic ve-

locities. Since the flow passage is diverging, the flow area is increasing, and the **Mach number** for the air likewise increases. The excess energy is finally dissipated by a strong shock wave forming in the diverging portion of the **subsonic diffuser**.

SUPERHETERODYNE RECEIVER. A radio receiver designed to obtain superior fidelity characteristics. The system includes a radio frequency amplifier, local oscillator, crystal mixer, intermediate frequency amplifier, second detector, video amplifier, and cathode follower output.

SUPERHIGH FREQUENCY. Radio frequencies between 3000-30,000 megacycles per second. It is abbreviated SHF.

SUPERNOVAE. Knowledge of supernovae has been increased in recent years by systematic search for them in photographs of clusters of **exterior systems** with the 18-inch Schmidt telescope of the Palomar Observatory and the further studies of many discovered supernovae with the 100-inch Mount Wilson telescope. These spectacular outbursts occur in all types of systems at the average rate of one per system in 400 years. The studies of Minkowski have shown that they fall into two groups:

Group 1. These supernovae are around absolute photographic magnitude 15.5 at maximum, or more than 200 million times as luminous as the sun. If one of them were placed at the distance of 10 parsecs from us, where the sun would be barely visible to the unaided eye, it would appear 14 times as bright as the full moon does to us. The spectra show extremely broad emission bands. The light variations resemble those of most normal novae (see **nova**); there is a rapid rise to maximum, followed at first by a rapid and later by a slower decline.

Group 2. The members of this group reach a maximum luminosity equal to about 20 million suns. After maximum they fade more slowly at first than do the members of the other group. The series of changes in their spectra resemble that of normal novae except on a greater scale. Supernovae of this group are probably more numerous than are those of the first group, but being fainter they are less readily detected.

Three recorded novae within the galactic system are supposed to have been supernovae. They are the nova of 1054 associated with

the Crab nebula, and the novae of 1572 and 1604.

SUPERREFRACTION. Under certain atmospheric conditions when the upper air is slightly warmer and drier than the surface air, radio waves can be guided around the surface of the earth to a greater distance than normal by bending due to refraction. It is not a detrimental condition except for interference with other stations on the same frequency.

SUPER-REGENERATIVE RECEIVER. In the ordinary regenerative receiver the sensitivity goes up as the **feedback** is increased, but if the feedback is increased to produce the maximum amplification (just before oscillations start) the circuit is unstable and breaks into oscillation. The super-regenerative circuit utilizes this high gain point without the instability, by introducing a voltage of low radio frequency in the plate supply lead. Since this voltage subtracts from the plate supply voltage every half-cycle, it will lower the net plate voltage to the point where any started oscillations die out. The circuit is adjusted so oscillations actually start to build up, giving very high gain, but are killed off at the low radio frequency (quench frequency) rate and so do not reach an objectionable amplitude. The quenching frequency may be generated by a separate oscillator **tube**, or may be generated by the regular detector tube in a so-called self-quenching circuit. The gain of these detectors is enormous, but they are subject to several limitations such as: poor quality, radiation and subsequent interference with other receivers, strong interchannel hiss, poor selectivity, etc. They are, nevertheless, quite widely used for reception in the **very high frequency** region.

SUPERSONIC. Sonic, super-.

SUPERSONIC AERODYNAMICS. The science of aerodynamics above the speed of sound. As development pushes the speed of aerodynamically-supported craft upwards, it begins to be apparent that there is a practical maximum speed beyond which it is not economical to fly in the atmosphere for prolonged periods. The first developments in supersonic aerodynamics obtained increased speed by designing airframes so as to overcome the supersonic effects. Every effort was

made to keep the flow over surfaces subsonic by sweeping back wings, locating airfoils where local velocities were subsonic, displacing stabilizing fins to insure that velocity high-spots of two surfaces did not coincide, and controlling surface junctions by smooth fillets. These modifications had only limited effects, primarily because of the great power requirements of supersonic flight in the atmosphere. It appears better to design manned aircraft for primary operation at extreme altitudes, where the thinness of the atmosphere is more favorable to supersonic flight, and be satisfied with subsonic flight inside the atmosphere. Supersonic flight of a missile cannot be economically postponed until the reaching of empty space; it will occur during ascending flight according to the acceleration history dictated by its design. Although the missile will eventually become a ballistic space vehicle, during its guided flight upward it is subject to lift and drag effects, even though it may have no airfoil surfaces.

SUPERSONIC DIFFUSER. Diffuser, supersonic.

SUPERSONIC FLOW. In aerodynamics, flow situations associated with greater than sonic velocity flight. There are two types of flow patterns which result in supersonic flow: *compressive* and *expansive*. In both supersonic flow and subsonic flow, drag, increase of drag with incidence angle, lift-curve slope, coefficient of moment, and other parameters retain the same sign in either case. However, unlike subsonic flow, a supersonic airstream accelerates along an expanding channel and becomes less dense. This is outlined more clearly by the following summary:

	CONTRACTING DUCT	EXPANDING DUCT
Subsonic flow	Accelerates Rarefies slightly	Decelerates Compresses slightly
Supersonic flow	Decelerates Compresses	Accelerates Rarefies

In a supersonic flow the following conditions are typical: (1) A pressure signal can be felt only within the limits of the **Mach fan** or **cone** since it will travel at the local speed of sound. (2) A total pressure tube does not experience the free upstream total pressure; it does not measure the total pressure of the

flow. (3) A static pressure tube experiences free stream static flow conditions. (4) A thermometer at rest measures **total temperature**. (5) The pitot static tube does not measure static pressure, but **dynamic pressure**. (6) A fluid passing through an expansion fan can be reduced to a subsonic velocity, can experience a decrease in static pressure, an increase in dynamic pressure, and a decrease in the local enthalpy. It also accelerates. (7) A great increase of drag occurs (as much as 10 times subsonic). (8) Shock waves form, giving rise to discontinuities in the flow patterns over aerodynamic surfaces. (9) Aerodynamic heating begins to affect structures and passengers. (10) Automatic controls and power aided control systems are required to overcome the tremendous forces generated on control surfaces by supersonic pressures.

SUPERSONIC NOZZLE. Nozzle, Supersonic.

SUPERSONIC REGION. A region in which the fluid flow is supersonic as contrasted to subsonic, e.g., where the flow is supersonic with respect to a missile surface and remains that way downstream. (See Fig. on Page 603.)

SUPERSONICS. The general subject covering phenomena associated with speed higher than the speed of sound (as in case of aircraft and projectiles traveling faster than sound). At one time, this term was used in acoustics to denote the general subject of high frequency sound (**ultrasonics**). Such usage is now deprecated.

SUPER SPRITE. A British (Vickers Aircraft Company) 4200-pound **RATO** unit.

SUPPORT BASE. The place from which logistic support is provided for a group of launch complexes and their control center.

SUPPRESSOR GRID. An element between the cathode and plate in a **vacuum tube** designed to prevent the passage of secondary electrons from one electrode to the other. It is usually a third grid placed between the screen grid and the plate in a **pentode**.

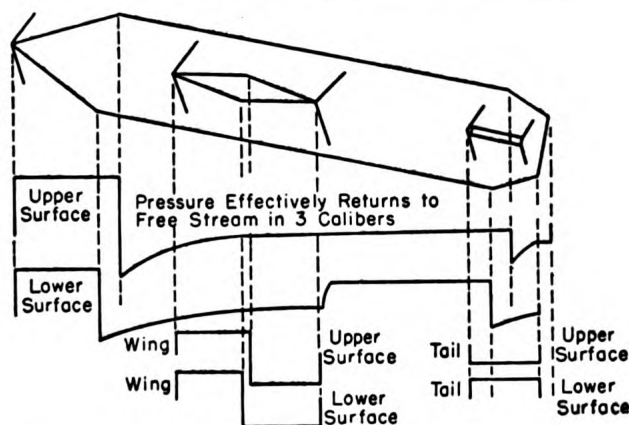
SURFACE BLAST. A nuclear explosion at the surface of land or water or at a height above the surface less than the maximum fire-ball radius.



Juno I, four-stage vehicle carrying first U.S. satellite, EXPLORER I into orbit. (Army Ballistic Missile Agency.) (*U.S. Army Photograph*)



SPUTNIK I (at ceiling) and interior of SPUTNIK II. The models of the first and the dog-carrying second Russian satellite were shown at the Brussels World Fair. At the bottom of the cone is the pressurized gondola, carrying the dog Laika. Above it are the instrument sphere and batteries. (*United Press Photograph*)



Supersonic pressure distribution over a body of revolution.

SURFACE-TO-AIR MISSILE. Missile, ground-to-air; missile, guided; model designation.

SURFACE-TO-SURFACE MISSILE. Missile, ground-to-ground; missile, guided; model designation.

SURFACE-TO-UNDERWATER MISSILE. Missile, ground-to-ground; model designation.

SURVEILLANCE RADAR. Radar, surveillance.

SURVEY. In engineering and cartography, the process of measurement of points on the earth's surface to establish their position on a reference surface (normally the spheroid of the earth). The objective is directions, including differences in elevation between points. The more accurate methods employ triangulation, as well as the establishment of traverses and levels, by use of optical measuring instruments, which are widely used to measure

angles. Under conditions where optical triangulation is impracticable electromagnetic systems are used; usually these are similar to **hyperbolic navigation systems**. In military usage, the following divisions of survey are made for artillery purposes: *Position area survey* which is a survey within the gun or missile area. *Target area survey* which is a survey of the area into which the guns fire, or the missiles are directed. *Connection survey*, which is a survey used to tie together the results of a position area survey and a target area survey.

SURVEY ACCURACIES. The United States Government specifications for horizontal and vertical control as determined by the U.S. Government Board of Surveys and Maps (adopted 21 May 1925) are as listed below.

Accurate surveys are of importance on test ranges in order to position instrumentation stations. They also limit the accuracy of surface-to-surface guided missiles which re-

	1st Order	2d Order	3d Order	4th Order
Triangulation				
Discrepancy (between computed and measured base)	1/25,000	1/10,000	1/5,000	Graphical
Closure				
Average	1 sec	3 sec	6 sec	
Maximum	3 sec	8 sec	12 sec	
Traverse				
Distance check	1/25,000	1/10,000	1/5,000	
Number stations between observed azimuths	10-15	15-20	20-35	
Probable error of observed azimuth	± 0.5 sec	± 2.0 sec	± 5.0 sec	

In the military practice, the following survey accuracies are used:

1st order	1/25,000 or better
2d order	1/10,000-1/25,000
3d order	1/5,000-1/10,000
Artillery	1/2,000-1/5,000
4th order	less than 1/2,000

quire prior knowledge of launch-point and target coordinates, e.g., ICBMs and IRBMs.

SURVEY CONTROL. In surveying or photogrammetry, the network of accurately known positions and elevations from which the remainder of the points in the system being developed are measured. The accuracy of control is usually described as first order, second order, third order, or fourth order according to the standards set forth under survey accuracy.

SURVIVAL PROBABILITY. The chance that a target will survive a given operation.

SUSCEPTANCE. The imaginary part of admittance.

SUSTAINER. A propulsion system, which travels with, and does not separate from, the missile. The term is usually applied to solid propellant rocket motors when used as the principal propulsion system as distinguished from an auxiliary motor, or booster; however, it sometimes denotes any missile stage except the booster.

SWAC. Standards Western Automatic Computer. The U.S. Bureau of Standards computer located at the Institute of Numerical Analysis, Los Angeles, California. It is used by the Naval Air Missile Test Center at Point Mugu, California.

SWC. Special Weapons Command.

SWEAT (TRANSPIRATION) COOLING. A technique for cooling combustion chambers or aerodynamically heated surfaces by forcing a coolant through a porous wall. Film cooling at the interface results.

SWEEP FREQUENCY. The rate at which a complete sweeping cycle occurs, e.g., the rate which a broad-band counter-measures receiver sweeps through its frequency range.

SWEEPBACK. The acute angle between a line perpendicular to the plane of symmetry, and the plan projection of a reference line on a missile wing. A high degree of sweep tends to alleviate the adverse effects of shock waves experienced in the transonic speed range. The lift on the swept-back wing is reduced by a factor of $\cos^2 \Lambda$, where Λ is the angle of sweepback. The effect of sweepback is to delay compressibility effects by in-

creasing the local critical Mach number. A subsonic wing section swept behind the Mach cone has less pressure drag than an unswept supersonic wing. At Mach 1, the swept wing is always superior to the unswept. The Mach number at which it is better to eliminate sweepback is a function of the wing thickness ratio. A thick wing requires sweepback to a higher Mach number than a thin wing.

SWEL. Special Weapons Equipment List.

SWINGING CHOKE. A variable inductance choke often used as the input choke for a smoothing filter of a power supply. The requirements for the input choke vary with the load on the filter so one value of inductance is needed for no load (other than the bleeder across the filter output) and a much lower value is needed when load is applied. By proper adjustment of the air gap in the core of an iron-cored choke, this variation in inductance can be made automatic as the current through it varies with the load demand.

SWITCHING. The connection of two points of a network at controllable instants of time. An alternative term is clamping.

SWOD MARK 9 MODEL "O." A U.S. missile popularly called the Bat. It was an air-to-surface glide bomb, using a radar homing form of guidance. It was used operationally during the latter part of World War II.

SWR. Standing wave ratio.

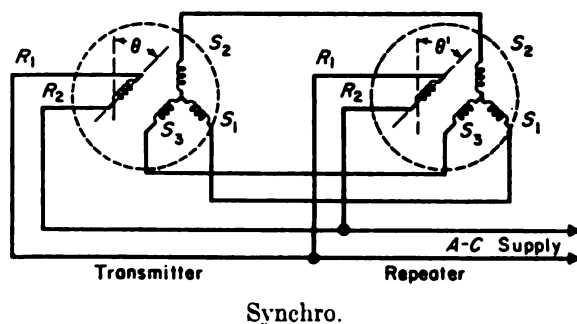
SYMBOLIC LOGIC (MATHEMATICAL LOGIC). A mode of developing and representing logical principles through the use of symbols for classes, propositions, etc., rather than a theory of logic. It provides an exact canon for deduction in general, and is usually developed by rigorous deduction from postulates and definitions.

SYMMETRIC. Arranged in accordance with a certain similarity with reference to a certain geometrical entity or position, which may be a point (center or point of symmetry), a line (axis of symmetry), or a plane (plane of symmetry), etc. A symmetric function is transformed into itself when its variables are interchanged in pairs.

SYNC SIGNAL (SYNCHRONIZING SIGNAL). The signal employed for the syn-

chronizing of **scanning**. In television, this signal is composed of pulses at rates related to the line and field frequencies.

SYNCHRO. The universal term applied to any of the various synchronous devices as the Selsyn, Autosyn, motor torque generator, Mag-slip, and Siemens whose purpose is to measure an angular position at one point and reproduce it at a remote point. Theoretically a synchro device is treated as a salient-pole, bipolar, a-c excited synchronous machine. The standard signal and control synchro has a two-pole, single-phase, rotor field and a Y-wound, single-phase, variable-voltage stator. The transmitter of the synchro, whose rotor is geared to (or otherwise linked with) mechanical equipment whose motion is to be measured, is also termed a generator, synchro-generator, or Selsyn-motor. The synchro has a rotor that is free to rotate, and is damped to prevent excessive oscillation before coming into correspondence with the rotor of the transmitter. Electrical synchro devices are frequently used for remote control or indication. (See figure.)



SYNCHRO RESOLVER. A device which uses a **synchro** to convert angular data into voltages. The voltages are proportional to the angles.

SYNCHRONIZING RADIO CIRCUITS. There are various types of synchronizing requirements in the field of radio and television engineering. In certain applications two or more **oscillators** need to be synchronized, i.e., tied together so their frequencies remain the same. This may be accomplished by injecting into each circuit a synchronizing signal from some common source (which may be one of the oscillators being synchronized). It is characteristic of many oscillator circuits that they will lock in frequency with an injected

signal if its frequency is near the natural frequency of the oscillator or is a **harmonic** of the natural frequency. In **television** it is essential that the reproducing circuits of the receiver be synchronized with the transmitter camera device so the reconstructed scene will have its components in the proper places. This is accomplished by transmitting synchronizing pulses from the **transmitter**. In many electronic devices the synchronization of various components of the system plays an extremely important part, but the basic method is that used for two oscillators.

SYNCHROSCOPE. A high-precision **cathode ray oscilloscope** having a horizontal sweep which is adjustable in phase and speed. It is used for precise analysis of waveforms.

SYNERGY. A term coined by Oberth to describe the compromise between the most efficient ascent of an escape vehicle when fired horizontally due east, and the avoidance of air resistance, etc., e.g., the ideal velocity for a synergic ascent is between 37,800 ft. per sec. and 39,400 ft. per sec. which would have 2300 to 6900 ft. per sec. in energy requirements for escape from the atmosphere.

SYNOPTIC. A chart, such as the ordinary weather map, which shows the distribution of meteorological conditions over an area at a given moment.

SYSTEM. (1) A specified region, or portion of matter, containing a definite amount of a substance or substances, arranged in one or more phases. (2) A plan of arrangement of terms or entities, especially those composing a larger aggregate. Examples of this second meaning are in U.S. Army terminology, a group of equipments integrated to perform a function. For example, a guided missile weapons system consists of the missile proper, and all ground and aircraft equipment necessary to operate it. However, a **guided missile system** is composed of a number of subordinate systems, such as the **guidance system** (composed itself of the intelligence system and the control system); the **propulsion system**, the **fuel system**, the **telemetry system**, the **destruct system**, the **armament system**, etc.

SYSTEM, ATTITUDE CONTROL. Automatic pilot.

SYSTEM PHASING. In program planning, e.g., missile production, a system used for adjusting the acquisition of all components to the longest lead time item, and identifying and scheduling all action necessary to achieve a complete system by a programmed date.

SYSTEM RELIABILITY. The probability that a system will perform its specified task under stated tactical and environmental conditions.

SYSTEM, STABLE. A system that can undergo considerable variation in external conditions, such as temperature, pressure, etc., without fundamental change.

SYSTEMS ENGINEERING. An engineering approach which organizes men, materials, and technologies for the purpose of developing an optimum device. Systems engineering covers two basic fields that are generally considered to be relatively independent, technical and administrative coordination. The technical aspect of systems engineering deals with the compatibility of the physical components which go to make up a weapons system; it is the effort which insures that each component fits physically, dynamically, and functionally with other components of the system. The administrative function deals with the problems of manpower utilization, procurement, scheduling, cost control, reporting, etc.

T

T. (1) Temperature, absolute (T), temperature, Kelvin (T), temperature of freezing point of water (absolute, T_0) (ordinary t_0), ordinary temperature (t), critical temperature (t_c or T_c) static temperature (propulsion) (t). (2) Time (t). (3) Reverberation time (T). (4) Transport number (T) (5) Radioactive half-life (T or $t_{1/2}$). (6) Oscillation period, or period of a periodic motion (T).

T-50. The **Matador** solid propellant booster. It had a burning time of 2.5 seconds.

T-131. A small U.S. Air Force rocket, 2½ inches in diameter.

Ta. **Tantalum.**

T/A. **Table of Allowance.**

TAB. In aerodynamics, a **trimming tab** is a small auxiliary airfoil installed on a control surface to make adjustments for balance in trim.

TAC. **Tactical Air Command.**

TACAN (TACTICAL AIR NAVIGATION). A system whereby the distance and bearing of an airplane from a fixed point is indicated on dials, or other devices within the airplane. Ultra-high-frequency signals pass between airplane and ground station, the operator in the airplane tuning to the station frequency. Because of the **line-of-sight** nature of these high-frequency waves, the effective range is limited by earth curvature, and many ground stations are required in a complete system.

TACTICAL DOCTRINE. Standardized employment of weapons based on prior experience; doctrine is normally prescribed for field forces in suitable publications.

TACTICAL MISSILE. In U.S. Air Force terminology, a guided missile employed on an Air Force tactical mission. An example is the TM-61, **Matador**.

TACTICS. The art of employing field forces and their material for best prosecution of a battle; pertains to military operations ensuing after contact with an enemy.

TAD. **Target Area Designation.**

TAF. **Tactical Air Force.**

TAIFUN. A German World War II surface-to-air missile. It was some 6 feet in length, 4 inches in diameter and weighed 43 pounds at take-off. It carried approximately 1.3 pounds of explosive and 26 pounds of propellant. It used a 1200 pound thrust (2 second duration) nitric acid-butyl ether rocket motor. It attained a velocity of 3000-3500 feet per second, and had an effective region up to 50,000 feet altitude.

TAIL CONE. A segment or component having a cone or conelike shape at the rear end of something, such as the tapering rear part of an airplane fuselage; an **exhaust cone**.

TAIL CONTROL. A method of missile control using control surfaces at the rear of the body. Lateral forces are obtained from fixed **lifting surfaces** mounted on the body, generally near the midsection, the entire configuration being deflected to an **angle of attack** by the tail control surfaces. A wingless tail control design may be achieved by omitting the wings, and obtaining the desired lift from the angle of attack of the body.

TAIL GRAB (MISSILE RETAINER). A device employed to secure a missile to its launcher by "grabbing" or holding the missile tail section at strong points to prevent missile motion until the desired thrust level is reached. Release is accomplished at the instant of launch.

TAILLESS (ELEVON) CONTROL. A method of missile control using but one set of surfaces with control flaps located at the trailing edge, the fixed surface providing the lift

and the moveable surfaces the necessary lateral and longitudinal control.

TALOS. A U.S. Navy air missile (SAM-N-6), developed by the Applied Physics Laboratory of Johns Hopkins University under the Bureau of Ordnance. Its dimensions: 20 feet in length, 30 inches in diameter, and 3000 pounds in weight. Its performance data include "more than 65 miles range." Along with the **Terrier**, the Talos resulted from development work done in connection with the **Bumblebee** project begun late in World War II. Talos powerplant was developed by McDonnell Aircraft, and was a kerosene-burning ramjet (with a solid-propellant booster for take-off. The Farnsworth Division of the International Telephone and Telegraph Company made the guidance equipment. Out of the Talos research came the **Tartar** missile, designed to be its short range complement. (See **missile, guided**.) See also illustration facing Page 411.)

TANDEM MISSILE. A fore and aft configuration used in boosted missiles, long range ballistic missiles, satellite vehicles, etc. Stages are stacked together in series and are discarded or staged at burnout of the propellant for each stage.

TANK CIRCUIT. An inductor and a capacitor in a parallel-connected **resonant circuit**. Since such a circuit has the ability to store energy for a short period of time, it acts as a reservoir or tank. Hence the term tank circuit.

TANK CIRCUIT, K OF THE. The ratio of the **tank circuit** volt-amperes to watts dissipated, including the load, is sometimes called **K**. This ratio is more generally known as **Q**.

TANTALUM. Metallic element. Symbol Ta. Atomic number 73.

TAPE, MAGNETIC CORE. A toroidal core formed from thin magnetic tape wound in a tight, continuous spiral.

TAPE RECORDER. A device which records information by magnetization of the magnetic particles adhering to a plastic or paper tape.

TAPER. In aerodynamics, the change in dimensions from the root to the tip of an air-

foil. Taper can occur in plan form or in thickness. Thickness taper causes an airfoil to have less movement of its center of pressure for changes in **angle-of-attack**, increases the **coefficient of lift**, and decreases the **coefficient of drag**. Wings tapered in plan form cause the center of pressure to move more for changes in angle-of-attack, to increase the coefficient of lift and to lower the drag.

TARE. (1) *Telemetry Automatic Reduction Equipment*. Equipment consisting of arbitrary function generators for data correction, a control console for adjustment of calibrators, multi-range voltmeters, monitor cathode ray tubes, automatic time recording devices for marking oscillograph records with range timing, linear time function generators for validation of the analog data provided and calibration slide cutting equipment for photoelectric linearization of the data. The TARE equipment at the Air Force Missile Test Center, Patrick Air Force Base, Florida, can accept FM/FM telemetry tape recordings or PDM tetemetry recordings and can record the linearized data on oscillographs or punched paper tape. (2) Obsolete term for the empty weight of a flight vehicle, i.e., less all fuel and payload. (See **weight, bogey**.)

TARGET. (1) An enemy vehicle, installation, facility, or other material or personnel against which attacks are to be made. (2) Any object capable of reflecting a **sonar** or **radar** signal. (3) A substance or object exposed to bombardment or irradiation. (4) The **anode** or **anticathode** of an x-ray tube, from which the x-rays are emitted as a result of electron bombardment. (5) The initially stationary atom or nucleus in a **nuclear reaction**.

TARGET ACQUISITION. First appearance in a radar or other search system of recognizable intelligence of a target. Also termed detection.

TARGET ANALYSIS. The study of the characteristics of a target in the light of the capabilities of the armament planned to be used against it, for the purpose of determining the most efficient means of attack. Target analysis includes consideration of the type and size of warhead and fuze to be used, the firing data computation (including accurate location of target and selection of aiming point), the

number of weapons to be used to obtain the desired effect, and the types of (artillery) fire to be placed upon the target. It also includes the post-attack analysis to determine the firing effect. The analysis of the probable effect on the target involves use of the following concepts: **single shot hit probability**, **standard deviation**, **dispersion ladder**, **probable error**, circular probable error, median probable error, **bias**, assurance, destruction, and warhead yield. (See figure under **kill probability**.)

TARGET BOARD. An accurately surveyed marker, usually illuminated for night work, which is used to aim and orient observational instruments. It is a permanent or semi-permanent installation some distance from the observing location, having a quadranted circle of alternate black and white segments, which form vertical and horizontal markings on which to train the cross-hairs in the observing instrument.

TARGET COMPLEX. A group of targets having a common strategical or tactical interest.

TARGET DISCRIMINATION. That quality of a **guidance system** which enables it to distinguish a target from its background or between two or more targets in close proximity.

TARGET DRONE. A pilotless aircraft used exclusively as a target for anti-aircraft weapons.

TARGET FADE. A decrease or loss of signal due to interference or other phenomena. (Tracking loops usually include memory circuitry to cause the radar to continue to track at the same rate during this period.)

TARGET IDENTIFICATION. The act of determining the nature of a target and whether it is friend or foe. (See **identification**, **friend or foe**.)

TARGET NOISE. Random reflections of a transmitted radar signal caused by the target having a number of reflecting elements randomly oriented in space. (See **scintillation**.)

TARGET PROFILE AREA. A sectional area of a target, as it affects detection, radar reflection and vulnerability.

TARGET, RADAR. Any radio frequency reflecting object of particular interest in the path of a radar beam.

TARGET SCINTILLATION. The apparent random movement of a target's center of reflectivity during the course of an operation.

TARGET VULNERABILITY. The resistance to destruction which a target possesses with respect to a weapon which is intended to destroy it.

TARGET WEIGHT. Weight, **bogey**.

TARTAR. A surface-to-air missile smaller than, and having better performance than the **Terrier**. It was manufactured by Convair, with Raytheon providing the shipboard radar control equipment. The Navy planned in early 1957 to equip destroyers and some cruisers with this missile. (See **Missile, guided**.)

TARZON. A U.S. World War II 6-ton guided bomb using a radio command **guidance system**.

TAURUS (The bull). Taurus, the second sign of the **zodiac**, is a constellation of very great antiquity, two of its open **clusters**, the Pleiades and the Hyades, being frequently referred to in the Bible, and Aldebaran, its brightest star, is well known.

Aldebaran (Alpha Tauri) is the standard first **magnitude** star of the northern hemisphere. The star is distinctly yellowish in appearance and has a measured diameter about 60 times that of the sun. It is a **double star**, but difficult to resolve except with moderately large instruments.

The two asterisms, the Pleiades and the Hyades, are both open clusters, i.e., groups of stars moving through space together. The Pleiades group is also noteworthy in that it is filled with diffuse **nebulous** material.

There are a number of double stars available for observers with small telescopes.

Tb. Terbium.

Tc. Technetium.

TBM. *Tactical Ballistic Missile; Theater Ballistic Missile.*

TDN. A U.S. Navy missile of conventional light plane type designed for use as an assault drone. It was a twin-engined tricycle high-

wing monoplane carrying a two thousand pound general purpose bomb and employing television-radio command guidance. It was used operationally against the Japanese in the South Pacific, notably at Rabaul.

TD2N-1. A U.S. Navy jet drone developed during World War II. It was a high wing monoplane, with a normal horizontal stabilizer and two pendant rudders and vertical stabilizers hanging from the tips of the horizontal stabilizer. The jet motor was faired into the bottom of the fuselage, with its scoop opening just ahead of a point below the leading edge of the wing.

Te. Tellurium.

TE-5. A German World War II antiaircraft guided missile. It was propelled by **mercaptan** (used as a **monergol**). Experiments were abandoned since the propulsion unit was unstable, and the combustion product was toxic.

TECHNICAL DIRECTION. The act of directing by a central agency of a weapon system development being done by a number of independent industrial/university groups. The concept is one of a systems engineering group giving broad technical direction to the program as a whole, and detail direction where required to further the effort.

TECHNICAL TEST CONTROL. The specialized or professional guidance and direction exercised with respect to the Missile Test Center aspect of tests, which includes the authority to schedule, alter or stop individual tests in accordance with dictates of safety, undue interference to other tests, technical feasibility of the range to accept any test, and limitations imposed by available test resources.

TECHNICAL TEST DIRECTION. The determination and execution of test programs in accordance with directives or contractual authority of the sponsoring service, including the determination of technical validity of test objectives, the formulation of general test programs and detailed test plans, the preparation of articles to be tested, the prosecution of tests and evaluation of test data, the reporting of test results, and the reorientation of the test program and plans based on these data.

TECNETIUM. Radioactive Element. Symbol Tc. Atomic number 43.

TELEGRAPHY. Communication by telegraph, whether the older manual type or the more recent automatic or printing type, is done by a code of electrical pulses. In the manual type the operator sends a certain combination of pulses for each letter of his message and the receiving operator then transcribes them into the characteristic letters. In the more complicated automatic types the sending operator uses a keyboard similar to that of a typewriter, and the equipment transforms the striking of a key into the proper signals (not the same code as for manual operation) and a machine at the receiving end selects the proper letter and the message is typed. The message may be transcribed to a punched tape and then transmitted automatically.

TELEMETER. The equipment for **telemetering**.

TELEMETER BAND. A subcarrier band (18 in the standard FM/FM telemetering system) which is used to modulate a carrier. The center frequencies of the 18 bands are separated by the ratio of 1.3:1 (except between 14.5 and 22 kc). (Contrast with **telemeter channel**.)

TELEMETER CHANNEL. An information channel which may be continuous or sampled. Multiple channels may be handled on one telemetering band by **multiplexing**.

TELEMETERING. The measurement of various quantities at a distance by the transmission of a suitable signal by telegraph, telephone or radio.

TELEMETERING, FM/FM. A standard telemetering system used at all missile development centers in the United States. The 18 subcarrier bands are frequency modulated and the RF carrier is also frequency modulated: hence the term FM/FM. (See Fig. 1 on Page 611.)

TELEMETERING PICKUP. A device used to measure and convert data to be telemetered into a form suitable for modulation of the telemetering link. Pickups are used to measure strain, pressure, voltage, vibration, acceleration, fuel flow, position, counters (cosmic ray), temperature, etc. Variable voltage, resistance, reluctance, capacitance or inductance can be used. This equipment is sometimes

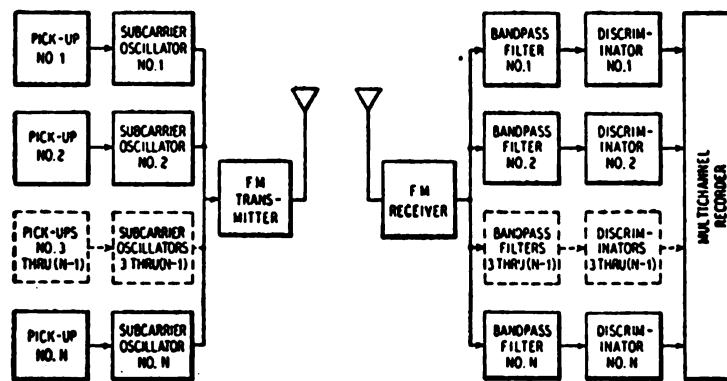


Fig. 1. Simplified FM/FM telemetry system.

termed end organ, end instrument, or transducer.

TELEMETERING, PULSE DURATION MODULATION (PDM). A system of **telemetry** used where time division multiplexing is acceptable. A large number of channels of information can be handled, but the frequency response is reduced in comparison to the subcarrier bands of the FM/FM system. The radio frequency carrier may be modulated by either **frequency modulation** or **phase modulation**.

TELEMETERING, PULSE WIDTH MODULATION (PWM). Sometimes termed **pulse duration modulation**. A telemetry system in which a voltage-generating end instrument is sampled briefly to determine its instantaneous level. This level is converted, by appropriate circuitry, into a pulse whose duration is a measure of the original voltage level. This, and similarly generated pulses, are then used to modulate a radio carrier frequency.

TELEMETERING SYSTEM. The complete measuring, transmitting, and receiving apparatus for remotely indicating, recording and/or integrating information. (See Fig. 2.)

TELEMETRY. The process of transferring information from one point to another remote point, usually electromagnetically.

TELEPHONY. The science of communicating speech by electrical means over wire circuits. The complete system has at least three fundamental components, the transmitter which converts the sound variations into electrical variations, the transmission circuits and the receiver which converts the electrical variations back into sound.

TELERAN. A *television* and *radar navigation* system. The television image of a ground PPI and map are presented in the aircraft. The system also shows weather data.

TELESCOPE. A device which may consist of a single lens or mirror, but frequently is a telescopic system, by which distant objects may be observed.

TELESCOPIC PHOTOGRAPHIC RECORDER. A transportable, single-telescope recording field instrument for tracking missiles. It provides data on velocity, acceleration, spin rate, attitude, and position. Angular data and correlated time are film-recorded.

TELETYPE. A **telegraph** system which employs a typewriter mechanism for transmission and reception. Pressing a given key at the transmitter initiates a coded signal which causes the corresponding key to be actuated at the receiver.

TELEVISION. The transmission and reception of visual images, either still or motion, by

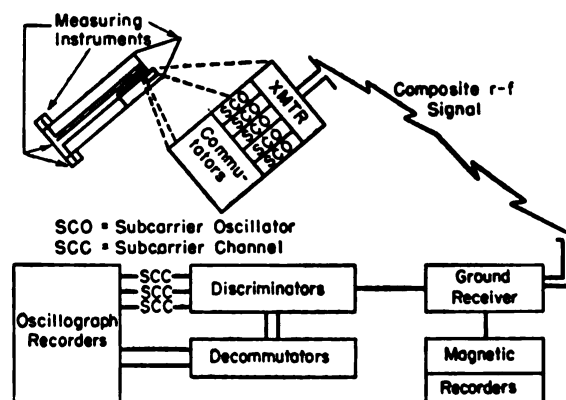


Fig. 2. FM/FM telemetry system.

electrical means, commonly by radio, for instantaneous viewing without permanent recording. For a practical system certain fundamental components or functions are necessary:

- (1) Camera device to pick up the scene.
- (2) Transducer to convert the light impulses of the scene to corresponding electrical pulses.
- (3) Transmitter to convert the electrical pulses into proper form to be transmitted to the receiver.
- (4) Receiver to pick up the transmitted signals and convert them to the proper form to apply to a transducer.
- (5) Transducer to convert the electrical pulses back into light in a reproduction of the original scene.

TELLURIUM. Chemical element. Symbol Te. Atomic number 52.

TEMPERATURE. Fundamentally, temperature is a manifestation of the average translational kinetic energy of the molecules of a substance due to heat agitation, and is measurable by any one of many physical effects due to changes or differences in this energy. Thus, substances expand, their electrical resistivity changes, gases and vapors exert varying pressure, the viscosity of fluids alters, etc., as the temperature varies; and the state of aggregation of any substance (whether solid, liquid, or gaseous), under a fixed pressure, depends primarily upon the temperature. The temperature of a vacuum may be defined as the temperature of a small body placed in it and in thermal equilibrium with it. All measurements of temperature, upon whatever principle they are based, are comprised under **thermometry**. (See also **temperature scales**.)

TEMPERATURE, ABSOLUTE. (1) The temperature measured on the thermodynamic scale. (2) The temperature measured from the **absolute zero** (-273.16°C). Degrees centigrade $+ 273.16^{\circ} =$ degrees absolute. (See **temperature scale, Kelvin**, and **temperature scale, absolute**.)

TEMPERATURE LIMITS, PROPELLANT. The limiting temperatures on the stability of a **solid propellant**. When the upper temperature is exceeded, the propellant becomes plastic or melts; when the temperature falls below the lower limit, it becomes brittle and cracks.

TEMPERATURE RECOVERY FACTOR. In aerodynamics, the ratio of actual temperature rise in the boundary layer to the **adiabatic** temperature rise.

TEMPERATURE SCALES. See **temperature scale, Centigrade**; **temperature scale, Fahrenheit**; **temperature scale, Kelvin**; and **temperature scale, Rankine**.

TEMPERATURE SCALE, CENTIGRADE. A temperature scale based on the mercury-in-glass thermometer, with the freezing point of water defined as 0°C and the boiling point defined as 100°C , both under conditions of normal atmospheric pressure.

TEMPERATURE SCALE, FAHRENHEIT. A temperature scale with the freezing point of water defined as 32°F and the boiling point as 212°F , both under conditions of normal atmospheric pressure. (See also **thermometer**.)

TEMPERATURE SCALE, KELVIN. A thermodynamic temperature scale based upon the efficiency of a reversible heat engine, operating in cycles between two heat reservoirs. The temperatures of the two reservoirs are in the same ratio as the quantities of heat transferred between the reservoirs and the machine. In this manner the temperature ratio becomes independent of the working substances. To fix the temperature values themselves, zero on this scale is defined as that temperature of the heat sink at which the efficiency of the heat engine is 100%. The scale may be related to the Centigrade scale by defining the size of the degree to be the same in both cases, and by defining the ice point on the Kelvin scale as occurring at 273.16 degrees. (See **Carnot cycle** and **thermometer**.)

TEMPERATURE SCALE, RANKINE. An absolute temperature scale on which the difference of the boiling and freezing points of water is 212° and the zero of which is the absolute zero of temperature. The freezing point of water, under normal atmospheric pressure, is at 491.7°R . One degree Rankine ($^{\circ}\text{R}$) = one degree Fahrenheit ($^{\circ}\text{F}$). (See also **thermometer**.)

TEMPERATURE SENSITIVITY, PROPELLANT. A measure of the effect of grain tem-

perature on the propulsive thrust derived from a **solid propellant** rocket. It is usually expressed as a percentage increase of chamber pressure accompanying a stated increase in temperature. It is also expressed as the pressure change per degree change in temperature. In some cases the temperature sensitivity is so great as to limit considerably the operating conditions of rockets. **Ballistite**, for example, must be used between 0°F and 120°F. Other propellants exhibit no adverse characteristics over a much wider range of temperatures.

TENSILE STRENGTH. The resistance offered by a material to tensile stresses, as measured by the tensile force per unit cross-sectional area required to break it.

TENSION. A force, usually in a wire, string or rod, supporting a weight or otherwise stretched between two points.

TERMINAL. A point at which any element of a **network** may be directly connected to one or more other elements.

TERMINAL PHASE. (1) A **guidance** phase covering that portion of a missile's trajectory from the end of midcourse guidance to the impact with the target. (2) For ballistic missiles, the terminal phase is that part of trajectory from **reentry** to **impact**.

TERMINAL VELOCITY. In aeroballistics, the greatest speed a body attains under ideal conditions at the end of operation of its propulsive phase. It is also the impact velocity; thus it is not in this case the maximum velocity, since aerodynamic *drag* will make the impact velocity much less than the re-entry or burn-out velocity.

TERNARY FISSION. Fission, nuclear.

TERRAPIN. A U.S. rocket weighing 225 pounds used in the University of Maryland high-altitude research program. It was designed for a speed of 3800 mph. and an altitude of 80 miles. Its first flight was in the summer of 1956. It was a two-stage solid propellant type carrying 6 pounds of instruments. It was fired from Wallops Island, Virginia. It was approximately 15 feet in length and 6½ inches in diameter. It was designed for cosmic ray studies and upper-air temperature research. (See **missile, guided**.)

TERRESTRIAL REFERENCE(S). Properties of the earth and its atmosphere which are used, by means of their spatial variations, as bases of reference in missile guidance systems. They include the intensity of the earth's magnetic field, the topographic features of the earth (usually measured by radar) and the density, pressure and temperature of the atmosphere.

TERRESTRIAL REFERENCE GUIDANCE. **Terrestrial reference(s).**

TERRESTRIAL SATELLITE. A **circumterrestrial satellite** designed to orbit about the earth at a distance of between 1.087 and 2 times the radius of the earth. These figures apply to a circular orbit; if the orbit is elliptical, they apply to its major axis.) The terrestrial satellite has two fundamental characteristics which distinguish it from the vertical sounding rocket: (1) The capability of extended stay time at a great variety of altitudes, ranging from ionospheric levels to extra-atmospheric regions. (2) Horizontal rather than vertical motion at very high speed. This permits a rapid coverage of large portions of the planet. When moving in equatorial or slightly inclined orbits, the satellite sweeps over the equatorial and low-latitude regions in quick succession from daylight to night and back. When moving in a polar orbit or a highly inclined orbit, all or a wide range of latitudes are covered in a short time. Satellite measurements and observations are therefore of planetary scope, rather than of local character as are most surface measurements and high altitude rocket flights. (See figures on Page 614.) (See **Explorer**; **Sputnik**; **Vanguard**.)

TERRESTRIAL SPACE. Space, terrestrial.

TERRESTRIAL SPACE RESEARCH. See **Sputnik**; **Explorer**; **Vanguard Satellite Series**; **Farside**; and **meteors, artificial**.

TERRIER. A U.S. Navy beam-riding, surface-to-air anti-aircraft missile produced for shipboard and shore installations by Convair under the technical direction of the Applied Physics Laboratory (APL) of Johns Hopkins University. It is approximately 15 feet in length, less its booster. Its overall weight is about 3000 pounds. Its effective range is about 20 miles. Its booster and sustainer rockets are made by the M. W. Kellogg Company and Aerojet General. Ships now using

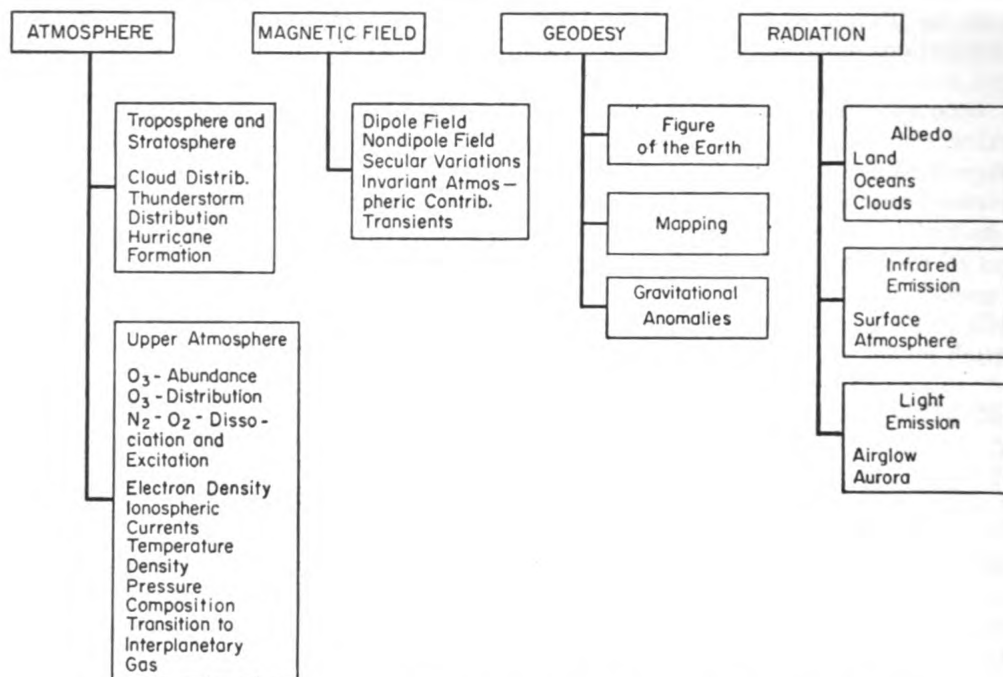


Fig. 1. Terrestrial satellite research by surveillance of terrestrial phenomena.

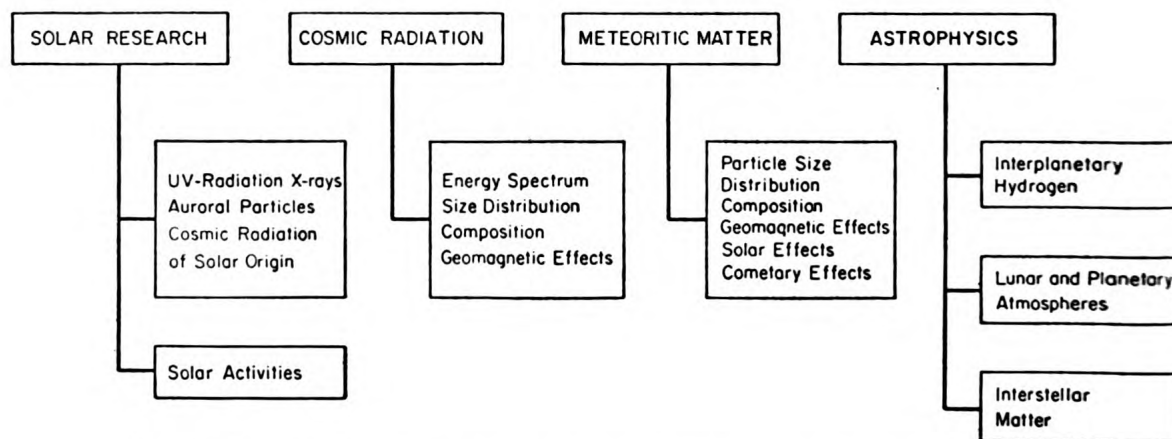


Fig. 2. Terrestrial satellite research by surveillance of extraterrestrial phenomena.

Terrier are Boston, Canberra (cruisers), and Gyatt (destroyer). Additional cruisers, frigates and aircraft carriers will be equipped with Terrier. (See **missile, guided.**) (See also illustration facing Page 411.)

TEST FAILURE. A failure to achieve a sought-after result by virtue of a miscalculation, inadequate equipment, or the like, during the research and development phase of a rocket missile or vehicle.

TEST-FAILURE LOAD. For a structural member the smallest load obtained by apply-

ing any of the following criteria to the results of static load tests: (a) The load which produces a permanent set (strain) or x inches per inch at a critical point in a primary structural member. (The value for x is selected to suit the particular material, structure and load situation.) (b) The load which produces a total deformation (either permanent or elastic) established as a limit by performance requirements. (c) The load which produces collapse or buckling; applicable if (a) or (b) does not apply. A factor-of-safety, depending on judgment, and varying between one

and one and a half, must be applied to allow for unknown or variable factors.

TEST VEHICLE. A rocket or jet powered craft used for testing of some technique or subsystem proposed for a missile system. Test vehicles include: launching test vehicles (LTV); propulsion test vehicles (PTV); control test vehicles (CTV); homing test vehicles, (HTV); guidance test vehicle (GTV), etc.

TEST POINT, MAJOR. A test point used to identify an over-all function of a missile subsystem.

TEST STAND. A device for holding a rocket motor or missile in position for captive or flight test.

TESTING, SERVICE. In U.S. Air Force terminology, service testing is of four types: (1) Research and development testing; (2) Factory acceptance testing; (3) Depot and modification center testing; and (4) Operational suitability testing. In U.S. Army Ordnance research and development terminology, the four types are: (1) Research and development testing; (2) Engineer testing; (3) User testing; and (4) Troop testing.

TESTS, EVALUATION. Tests conducted by a developing agency comprising examinations, investigations, or other observations necessary to determine the technical adequacy of the material undergoing test. Pilot or experimental models are subjected to these tests at the various laboratories and proving grounds prior to initiation of procurement of a production model.

TETRODE. A four-electrode electron tube containing an anode, a cathode, a control electrode, and one additional electrode that is ordinarily a grid.

TETRYL. Trinitrophenyl-methyl-nitramine $C_6H_2(NO_2)_3(NCH_3NO_2)$. It is a sensitive high explosive. It is the standard booster used for TNT shells.

TE-WAVE. A transverse-electric wave. It is also called an h-wave.

THALLIUM. Metallic element. Symbol Te. Atomic number 81.

TG-2. A U.S. Navy glide bomb developed during the early part of World War II. It

was tried out experimentally but was never used tactically. It was guided by a radio-television link.

Th. Thorium.

THEODOLITE. (1) An optical instrument for measuring horizontal and vertical angles. It is similar to a transit. (2) The term *theodolite* is frequently used loosely for a **phototheodolite**.

THERMAL DIFFUSIVITY. A parameter defined as the ration of thermal conductivity to the product of density and specific heat capacity. It is important in the evaluation of **solid propellants**.

THERMAL EFFICIENCY. Output, in heat units, divided by the heat supplied or chargeable, or divided by the heat of reaction of fuel input. In rocket propulsion, this term is not useful in comparing propulsive efficiencies. The weight of fuel consumed per unit thrust is a more significant property.

THERMAL JET ENGINE (AIR-BREATHING ENGINE). A jet propulsion engine which uses air to support combustion and for the creation of a high speed jet stream. (See **jet engines**; **propulsion**, **jet**.)

THERMAL JET ENGINES, TYPES OF. ramjet; pulsejet; turbojet; turborocket.

THERMAL NOISE. Shot effect.

THERMAL RADIATION. Radiation emitted by atoms or molecules excited by thermal energy, i.e., temperature. This thermal radiation ranges in wavelength from the longest infra-red to the shortest ultraviolet rays; its spectral energy distribution, however, depends upon the nature of the body and upon its temperature.

THERMAL REACTOR. Reactor, thermal.

THERMAL SHOCK. An undesired effect upon a material due to sudden, large changes in temperature. Such effects include structural failure, and great evaporation losses of low boiling fluids, such as liquefied gas, when charging them into warm containers. (See also **precooling**.)

THERMIONIC EMISSION. Electron or ion emission due to the temperature of the

emitter. Thermionic emission from solids is very sensitive to the state of the surface. It is used in **electron tubes** as a source of electrons.

THERMIONIC TUBE. Tube, thermionic.

THERMISTOR. A resistance element made of a **semiconducting** material which exhibits a high negative temperature coefficient of **resistivity**.

THERMISTOR BOLOMETER. A **bolometer** invented by Bell Telephone Laboratories. In one form, it is a thin film of semiconducting oxide deposited on a quartz or glass plate. The quartz crystal is resonant to one or more frequencies, and thermal distortion of it in a field of radio frequency energy produces a detectable current.

THERMISTOR (THERMAL RESISTOR). A partial conductor or resistor whose resistance varies with temperature in a definite desired manner. It is used in circuits to compensate for temperature variations in other parts, or to measure temperatures, or as a non-linear circuit element.

THERMOCOUPLE. A device consisting of two metals, one of whose junctions is kept at a fixed temperature. The **thermoelectric** electromotive force generated in the circuit is measured to give the temperature of the other junction, making a convenient and simple **thermometer**.

THERMODYNAMIC ANALYSIS OF ROCKET ENGINES. The principles of this method assume that a gas is heated, stored under pressure in a chamber, and then flows through the chamber exit (throat) and expands in a divergent nozzle, whereby the enthalpy is converted to kinetic energy. The resulting exhaust velocity is primarily a function of enthalpy difference between chamber and nozzle exit. The exhaust velocity determines the amount of thrust produced per unit weight of discharged gas and is therefore a measure of the performance of the respective propellant or externally heated working fluid. The determination of the fluid performance consists of three basic steps:

1. For a given heat release and chamber pressure determine the composition and the entropy of the gas in the chamber.

2. For the given exit pressure determine the exit temperature, composition and enthalpy of the gas.
3. With the gas enthalpy in the chamber and at the exit known, find the exhaust velocity from the enthalpy difference.

The actual conditions are simplified by the assumption that the expansion in the nozzle is isentropic so that the most laborious part of the computation is the determination of the equilibrium composition. (See entries following.)

THERMODYNAMIC ANALYSIS OF ROCKET ENGINES (METHOD OF FROZEN EQUILIBRIUM). The method of shifting equilibrium (which is discussed after this entry) assumes that the gas composition is at all times during the expansion process in equilibrium according to the instantaneously prevailing temperature and pressure, so that its exit composition is only a function of exit pressure and temperature. In practice this is probably not the case, since the atoms require a certain time to adjust themselves to the changed conditions and recombine. This time is called "relaxation time." The expansion time is very short, of the order of a few milliseconds. One must therefore expect a certain lag in recombination where heavier molecules are involved whose relaxation time is longer than that of light atoms of high diffusivity, such as hydrogen. Unfortunately, the relaxation times of dissociated molecules in rocket exhaust gases are not very well known and probably depend on many individual circumstances. However, as long as the pressure in rocket engines is high, such as in booster rockets, which work in the lower layers of the atmosphere and whose exit pressure is limited to some 0.6 atm, the number of collisions throughout the nozzle is still large, compared to that in space engines which may work with exit pressures of about 10^{-1} to 10^{-3} atm. Here, recombination requires very much longer nozzles.

Obviously, the extreme condition is that no recombination takes place in the nozzle so that the gas composition at the exit is the same as in the chamber. This case is even less likely to occur in practice than that of shifting equilibrium. It has, however, the attractive characteristic of computations that a large number of equilibrium composition determinations at the exit can be eliminated.

This method of performance analysis is known as method of "frozen equilibrium." If one computes the performance of a propellant accordingly, one obtains surprisingly accurate values for the exhaust velocity with "errors" compared to shifting equilibrium of the order of 5 per cent or less, provided the mixture ratio is not too close to stoichiometric. However, designating the chemical ratio of fuel to oxidizer as 50:50 for stoichiometric mixture ratio, then ratios of 60:50 or 40:50, i.e., 20 per cent more or less fuel than required for stoichiometric combustion, or greater deviations, provide "frozen" values which are close to the "shifting" values. The reason for the greater inaccuracy close to stoichiometric mixture ratio is the higher degree of dissociation. Fortunately, stoichiometric mixture ratio is of little practical value in most cases, because of high combustion temperature and because maximum specific impulse is usually attained at the above defined chemical ratios of 55:50 to 65:50, i.e., at 5 to 15 per cent (based on the total) more fuel than required for stoichiometric mixture ratio.

The reason for the comparatively small error in exhaust velocity in these regions is that the exhaust velocity is a function of T/M . In the case of frozen equilibrium, T is reduced while M is also reduced throughout the expansion process. These two effects are oppositely directed and largely cancel each other. The effect of the lower exit temperature (300-500°C lower than for shifting equilibrium), however, leads to greater gas density and therefore to much smaller exit area (or nozzle cross-sectional areas in general). As a result, the nozzle dimensions are seriously in error.

A salient comparison of shifting and frozen equilibrium calculations can therefore be summarized in the following statements:

1. Shifting equilibrium conditions are in most cases of conventional rocket motors more nearly fulfilled than frozen equilibrium.
2. Shifting equilibrium requires considerably more computational labor (unless done on the electronic computer) than frozen equilibrium.
3. The difference in propellant performance between the results of these two computation methods is small (within about 5 per cent), provided mixture ratios in the close vicinity of stoichiometric are not involved.

The frozen equilibrium method is therefore satisfactory for propellant performance comparisons.

4. For the determination of nozzle dimensions, shifting equilibrium should be used.

THERMODYNAMIC ANALYSIS OF ROCKET ENGINES (METHOD OF HELLER-WAGNER). A computational method particularly useful for liquid propellants without liquified gas components containing oxygen compounds, nitrogen compounds, hydrocarbons, etc. The method is based on the assumption that dissociation (except for the water gas equilibrium), can be neglected in all cases (at least for P_c 15 atm) up to 2,000°K (3,600°R). Since actual combustion temperatures lie between 2,000°K and 3,500°K (6,300°R), mostly around 3,000°K, it is necessary to take dissociation into account, in addition to the increase in sensible enthalpy. The method treats the additional sensible enthalpy and chemical enthalpy (dissociation energy) separately. The total enthalpy of a combustion gas is then described by the sum of the following terms:

1. Sensible enthalpy at 2,000°K, H_{2000}
2. Sensible enthalpy from 2,000 to 3,000°K, $C_p T$
3. Enthalpy due to dissociation.

The method involves graphical determination of H_{2000} , C_p and H_{Do} as functions of the number of oxygen atoms per carbon atom, B , for several values of hydrogen atoms per carbon atom, A . By using such plots enthalpy and entropy can easily be calculated with sufficient accuracy.

THERMODYNAMICS. The branch of physics dealing with the relationships between heat and other forms of energy, and the laws which govern their interconversion, especially in fluids.

THERMOELECTRIC PHENOMENA. The effects associated with the change of the contact potential of two metals with temperature. Hence, a current may be produced by keeping one junction at a different temperature from the other (Peltier effect). There is also an effect associated with the electromotive force generated in a wire which is in a thermal gradient (Thomson effect). The thermoelectromotive force of a **thermocouple** appears to be a combination of a "Peltier

electromotive force" at the junction and the Kelvin or "Thomson electromotive forces" in the two strips.

THERMOJET (THERMAL JET ENGINE).

An air-duct type engine in which thrust is obtained by scooping air from the surrounding atmosphere, compressing heating by combustion, and discharging the exhaust gases at high velocity. (See **jet propulsion**.)

THERMOMETER. An instrument used to measure the intensity of the heat in a body, i.e., its temperature, usually constructed so that the expansion of matter caused by heat furnishes the measure of the temperature. Instruments for measuring high temperatures are termed **pyrometers**, and are based upon measurements of the amount of radiation emitted by the hot body, or by measurement of the amount of radiation of a particular frequency or narrow band of frequencies, or by measurement of the change in resistance of a standard length of wire, or by the use of a **thermocouple**.

THERMONUCLEAR. Of or pertaining to **nuclear reactions** or processes caused by heat, especially to nuclear fusion caused by the intense heat of an atomic bomb explosion.

THERMONUCLEAR REACTION. A **nuclear reaction** in which the energy necessary for the reaction is provided by colliding particles that have kinetic energy by virtue of their thermal agitation. Such reactions occur at appreciable rates only for temperatures of millions of degrees and higher, the rate increasing enormously with temperature. The energy of most stars is believed to be derived from exothermic thermonuclear reactions. (See **carbon cycle**; **proton-proton chain**.)

THERMOPILE. A device consisting of several **thermocouples** connected in a cascaded grouping to give a multiplied thermoelectric current when heated. The thermocouple pile is used principally for detecting very slight variations in temperature. It is also used to detect infrared rays.

THERMOPLASTIC. A plastic which softens upon the application of heat and rehardens upon cooling. It can be softened and hardened repeatedly.

THERMOSET PLASTIC. A plastic which undergoes a chemical change upon the application of heat and which does not appreciably soften or deform if later reheated.

THERMOSPHERE. The region of the atmosphere in which the temperature increases continuously with altitude. (See **ionosphere**.)

THERMOSTAT. A temperature sensitive device which is used to control other devices by means of its reaction to temperature changes. In its simplest form it is a strip composed of two dissimilar metals laminated together. Their differential contraction or expansion temperature changes cause bending of the joined strip. This mechanical motion can be used to trip relay contacts, shut valves, or perform other control functions.

THICKNESS RATIO. In aerodynamics, the ratio of the maximum thickness of an **airfoil profile** to its **chord**. In supersonic aerodynamics, a thin wing is essential to avoid **shock wave** effects.

THOR. (1) The U.S. Air Force IRBM developed by Douglas Aircraft under guidance of Ramo-Wooldridge and the Ballistic Missile Division. The development contract was let in December 1955. The first launching was in early 1957. It uses the same North American Aviation LOX-RP-1 rocket engine as does **Jupiter**. The Air Force's designation for the Thor weapons system is *WS-315A*. The guidance for Thor (inertial) was being developed by A-C Spark Plug Division of General Motors. By the middle of 1958, approximately 20 firings of the Thor were reported in the press. Reports also stated that the missile would be sent overseas with Air Force squadrons before the end of 1958. (See **missile, guided**.) (See illustration facing Page 442.) (2) A British (Bristol) ramjet for missiles, having a turbine fuel pump and a capability of about Mach 2.5.

THOR ABLE. A series of U.S. Air Force advance multistage rockets using the **Thor** missile. On July 9, 1958 and July 23, 1958, Thor Able vehicles flew to an estimated 6,000 mile range successfully. In each of these tests a mouse was carried in a recoverable data capsule. Although the two missiles went the full range neither mouse was recovered. The Thor Able Program also includes a series of **lunar probes**, expected to total 12 in number.

On August 17, 1958, Thor Able I, also designated as Thor 127, the first lunar probe, was fired. It was a four-stage configuration, and carried a payload weighing 83.8 pounds, of which 25 pounds was instrumentation. The total weight was about 52 tons and the overall length was 88.1 feet. The first stage was a modified Thor intermediate-range ballistic missile. The second stage implied an Aerojet liquid propellant engine of 7500 pounds-thrust, supplemented by eight spin rockets. The third stage was a solid propellant 2500 pounds-thrust rocket, weighing about 400 pounds (this rocket was developed originally by the Allegheny Ballistics Laboratory for the Vanguard Program). The fourth stage utilized a 300 pounds-thrust, Thiokol solid-propellant rocket. The instrumentation included a photocell scanner, and telemetering for reporting meteorite impacts, magnetic field intensities and final stage chamber pressures. Data were to be collected by the U.S. Navy Minitrack Satellite Tracking System established for Vanguard. The function of the fourth stage rocket, which was to be fired by remote control, was to speed up the payload so it would orbit around the moon.

The firing was sponsored by the newly created Advanced Research Projects Agency and carried out by the U.S. Air Force and several of its contractors. The probe reached an altitude of about 50,000 feet after 77 seconds of flight where it exploded probably because of a failure in the propellant system. Other lunar probes are planned to use Jupiter as a first stage. (See also Pioneer.)

THORIUM. Chemical element. Symbol Th. Atomic number 90.

THREE-BODY PROBLEM. If it is assumed that three or more objects exist in the universe, each of them attracting every other in accordance with the law of gravitation, the problem of predicting subsequent positions and motions is commonly referred to as the three-body problem, or the n -body problem.

The two-body problem has been completely solved and the full solution may be expressed in comparatively few words and symbols. However, if we add one or more other bodies the solution becomes one of exceeding complexity and has never been accomplished in any form which is at all suitable for computational purposes. In fact, only one complete

solution has ever been made, in spite of the labors of practically all of the great mathematicians of past centuries.

Even though no general solution of the problem is available, nevertheless, there are several practical computational methods for determining the positions of planets and other members of the solar system, taking into account the gravitational attraction of all effective members. Such solutions are all made by successive approximations and various methods of computing perturbations, rather than by the application of any general solution.

A number of particular solutions of the three-body problem have been made by mathematicians, notable among them being the solution by Lagrange. He showed that it is possible for an asteroid to be stable in a position such that it is equidistant from both the sun and Jupiter. In this case the three objects would be on the vertices of an equilateral triangle and the asteroid orbit would have the same period as that of Jupiter. This case is illustrated in nature by the members of the so-called Trojan group.

This problem requires special methods of attack in astronautics, where the three bodies are the space ship, the planet or other astronomical body which the ship is leaving, and the body to which it is traveling. However, if the path of the ship approaches other bodies closely enough so that their attractions affect the path sensibly, then the solution of the problem must take cognizance of these effects.

THREE-DIMENSIONAL FLOW CHARACTERISTICS. Because of the complexity of their mathematical analysis, three-dimensional flow problems are sometimes attacked through approximate solutions assuming two-dimensional flow. In using this method, the differences between the two types of flow become important. For three-dimensional flow, as contrasted with two-dimensional flow, the following differences can be assumed: (1) The shock wave is weaker. (2) The shock wave angle is smaller (assuming the same half-angle). (3) Streamlines do not turn parallel to surfaces but approach them asymptotically. (4) Thermodynamic changes are not constant between the shock wave and the surface of the body. (5) Pressure, velocity, density, and Mach number increase through the shock wave, and increase along the streamlines after

the shock wave (in two-dimensional flow, they remain constant along the streamlines).

THREE-WAY VALVE. Valve, three-way.

THREE-WIRE SYSTEM. A direct-current or single-phase alternating-current system comprising three conductors, one of which (the neutral wire) is maintained at a potential midway between the potential of the other two.

THROAT. The smallest diameter of a duct. It is the constricted part of the rocket motor, at which the **Mach number** is unity, and the heating is most severe.

THRUST. (1) In jet propulsion, the force, in the direction of motion, resulting from the components of the pressure forces (in excess of ambient atmospheric pressure acting on all inner surfaces of the vehicle or missile and which are parallel to the direction of motion. Thrust less drag equals accelerating force. (2) The force exerted in any direction by a powered screw, as, the thrust of an **antitorque** rotor. (3) The force acting on a rocket motor due to the reaction caused by the expulsion of matter at high velocity. This force is given by the sum of all static pressures acting axially on the area elements of the solid wall surrounding the gas in the motor, taking into account also the forces acting on the exit area.

THRUST AUGMENTATION. Afterburning.

THRUST CHAMBER. In a liquid-propellant rocket, the assembly consisting of the **injector**, **nozzle** and **combustion chamber** in which mixing of liquid propellants takes place to form hot gases, which are then ejected through a nozzle at high velocity to give momentum to the system.

THRUST COEFFICIENT. In rocket motor design, a parameter which can be determined experimentally. It is a term by which the chamber pressure and throat area must be multiplied in order to obtain the thrust of the motor. Thus:

$$F = C_F p_c A_t,$$

where F is the thrust, C_F is the thrust coefficient, P_c is the chamber pressure and A_t is the throat area.

THRUST CONTROL. In propulsion and missile control, a system of altering the force and/or direction of **thrust** of a rocket engine for control of the missile flight path. One method is to mount the motor in moveable gimbals under control of an **autopilot**. An alternative is to swivel only the **nozzle**. Another method is to deflect the exhaust stream by controlled vanes. Still another method, which controls both force and direction of thrust, is to vary the fuel rate by flowmeters. (See **thrust vector control**.)

THRUST CORRECTION FACTOR. The ratio of actual thrust to theoretical thrust. (See **thrust, theoretical**.)

THRUST DECAY. Cut-off.

THRUST, EFFECTIVE. In a rocket motor, the theoretical thrust (see **thrust, theoretical**) less the effects of incomplete combustion and friction flow in the nozzle.

THRUST EQUALIZER (SOLID PROPELLANT ROCKET). A device used to prevent motion of a solid propellant rocket in the event of inadvertent ignition by permitting discharge of exhaust gases from both ends to result in a zero net thrust. The device is closed off or otherwise inactivated when the rocket is readied for use. A typical design would provide a blowout disc in the head end, approximately equal to the nozzle exit area.

THRUST HORSEPOWER. Equivalent horsepower of a rocket motor is given by:

$$HP = \frac{FV}{375}$$

where HP is the horsepower, F is the thrust, and V is the velocity in miles per hour.

THRUST, IDEAL. In a rocket motor, the maximum momentum thrust (see **thrust, momentum**) for zero exit pressure.

THRUST LOADING. The proportion of the thrust of a jet or rocket-propelled aircraft or other vehicle to its gross weight, expressed as the gross weight divided by the thrust in pounds.

THRUST METER. A meter for measuring thrust, especially of a jet engine or rocket. (See **reaction balance**.)

THRUST MISALIGNMENT. The difference between the actual and desired direction of thrust in a propulsion system; it adversely affects dispersion, the greatest effect occurring early in the flight when the flight velocity is low.

THRUST, MOMENTUM. The component of thrust caused by the change of momentum of the combustion gases between chamber and exit with respect to the rocket.

THRUST OUTPUT. The net thrust delivered by a jet engine, rocket engine, or rocket motor.

THRUST OF A PROPELLER. The forward pull exerted by a propeller in giving momentum to a mass of air behind it; the thrust is dependent upon the diameter of the propeller, its pitch, and its speed of rotation.

THRUST, PRESSURE. In a rocket motor, the difference between nozzle exit pressure and ambient pressure acting on the exit plane of the exhaust nozzle.

THRUST SPECIFIC. The ratio between the thrust of a jet reaction motor and the total propellant flow rate producing the thrust.

THRUST SPECIFIC FUEL CONSUMPTION. A figure of merit for thermal jet engines; the ratio of pounds of fuel consumed per second to pounds of thrust.

THRUST SPOILER. As applied to a jet engine, a system of shutters over the end of the jet pipe to destroy most of the positive thrust at idling speeds, and thus reduce the landing run. *Not in general use.*

THRUST, STATIC. The thrust produced by a jet engine, rocket motor, or the like, or by a propeller-engine combination, when held stationary.

THRUST STRUCTURE. The truss-work within which the propulsion unit is mounted. Its chief purpose is to transmit the thrust to the center line of the missile.

THRUST TERMINATION EQUIPMENT. A component of the propulsion system uniquely used to terminate thrust (and thus acceleration) at a predetermined cutoff time, to achieve proper positioning of the point of impact of the missile or payload. In liquid

rockets it can be achieved by stopping the flow of propellants; in solid rockets it is necessary to vent the combustion chamber at its forward end and thus achieve a net negative thrust.

THRUST, THEORETICAL. The force acting on a rocket motor if there is complete combustion and ideal flow in the nozzle.

THRUST VECTOR CONTROL. A means of controlling a missile by use of jet deflection devices which, in response to appropriate signals from the autopilot, maintains proper attitude and path control.

THUMPER. A General Electric Company project on ballistic missile countermeasures. (The project number was MX-795.)

THUNDERBIRD. A British surface-to-air missile made by the English Electric Co.

THUNDERSTORMS. Cumulonimbus clouds accompanied by lightning and thunder. Normally thunderstorms are accompanied by torrential rain for brief moments during the passage of the storm, but occasionally no precipitation reaches the ground. Often they cause hail and gusty surface winds of considerable velocity. Sometimes they are attended by tornadoes which cause great damage. Vertical velocities inside thunderstorms are extremely erratic and as high as 120 mph.

THYRATRON. A gas-filled grid-controlled soft tube which operates characteristically, so that starting from a high negative grid potential, current flow occurs suddenly at some more positive grid potential, after which the anode current is independent of the grid, and must be stopped by reducing the anode potential. (Thyratrons are used in radars mainly for switching or triggering in modulator circuits. Lower power versions are used in control circuits.)

Ti. Titanium.

TIAMAT MX-570. A U.S. surface-launched research vehicle produced under the guidance of the NASA. It weighed about 600 pounds and was 14 feet long. It had three wings and was powered by a liquid-propellant with solid propellant boost. Several versions of the vehicle were produced during the period immediately after World War II.

TILT ANGLE. A mathematical artifice used to program the trajectory of ballistic missiles from the vertical ascent toward the horizontal to get "on target." In practice, the tilt angle is not constant, but is slowly changed.

TILT TABLE. A table of accurate orientation with respect to the local gravity vector. Used to test accelerometers.

TIME. In the purely physical sense of the term, time is defined as measured duration. In accordance with this definition we say that two intervals of time are equal if a body, moving in **equilibrium**, moves over equal distances in the two intervals. The moving object is frequently referred to as the clock.

From the earliest recorded history the apparently moving sun has been adopted as the clock for regulating human affairs, and the apparent solar day is the interval of time between successive passages of the true sun across a local **meridian**. For many centuries upper culmination, or apparent noon, marked the beginning of an apparent day and local apparent time was the **hour angle** of the true sun. In 1925, to bring the apparent day into synchronism with that used in civil life, the beginning of the apparent day was transferred to lower culmination, or midnight, and the local apparent time defined as the hour angle of the true sun plus 12 hours.

The various hour angles, or local apparent times, were formerly recorded by the position of the shadow of a rod on a graduated dial known as a **sun dial**. Such an instrument is useful only when the sun is shining, and the need for mechanical clocks arose. As the development of these timekeepers progressed, with ever increasing accuracy, from burning candles, water clocks, sand glasses, and other such contrivances, down to the modern mechanical, electric, crystal and atomic clocks, it became evident that the apparent solar day is not constant in length throughout the year. These variations in length may be traced to the fact that the earth is not only rotating on an axis, but is also revolving about the sun in an **orbit**. The plane of the orbit is not perpendicular to the axis of rotation of the earth, and the angular motion of the earth in its orbit is not constant but in accordance with the elliptical motion described by Kepler's Law of Areas.

To assist in the development of mechanical

clocks, the mean solar day was introduced. This is a day which is the average, in length, of all apparent solar days in a given year. A purely fictitious object, known as the mean sun, was defined and a mean solar day is the interval between successive passages of this fictitious object across any local meridian. The mean solar day begins at lower culmination of the mean sun and local mean time is the hour angle of the mean sun plus 12 hours. The difference between local apparent time and local mean time, taken in the algebraic sense of apparent minus mean, is known as the equation of time.

The term local civil time is sometimes used as synonymous with local mean time. Prior to 1925 the mean solar day began at upper culmination (mean noon) and the civil day began at midnight.

All three of the different kinds of time thus far discussed are measured from the local meridian. Accordingly, only those people living in the same terrestrial **longitude** would have synchronous clock readings. To avoid this confusion the surface of the earth has been divided into a series of standard time zones. The different sorts of standard time will be discussed elsewhere, but standard time is defined as the civil time of some standard meridian.

While the sun provides the most convenient reference point for measuring time for everyday life, nevertheless it is not convenient for stellar astronomy because of the fact that the sun is continually moving eastward through the stars. Sidereal time is defined as the hour angle of the **vernal equinox**. Since the sun is apparently moving to the eastward through the stars, due to the revolution of the earth about the sun, there is one more sidereal day than solar day in the course of a **year**. A clock keeping sidereal time gains approximately 4 minutes each day on a mean solar clock, the sidereal clock agreeing with the civil time clock on approximately September 21. The **right ascension** of a star is measured from the vernal equinox in a direction contrary to the direction of apparent rotation of the **celestial sphere** and the sidereal time is the hour angle of the vernal equinox, and hence measured in the direction of apparent rotation of the celestial sphere. Therefore, sidereal time minus right ascension is equal to the hour angle of a star.

The standard unit of time for the physical

sciences is the mean solar day as defined above. The practical unit is $1/86,400$ part of the mean solar day and is known as the mean solar second. This is one of the three basic units of the so-called **c.g.s. system**.

However, beginning in 1960, the *American Ephemeris and Nautical Almanac* and the *British Nautical Almanac* tabulate positions of sun, moon and planets for ephemeris time, which has as its second the length of the tropical year at the beginning of the year 1900 divided by 31,556,925.97474.

TIME CONSTANT. (1) The time required for a varying quantity to reach $(1 - 1/e)$ of its total change (approximately 63.2 percent of its total change): *e.g.*, in electronics, in a capacitor-resistor circuit, the time in seconds for the capacitor to reach approximately 63.2 percent of its full charge after a steady voltage is applied; in an inductor-resistor circuit, the time in seconds required for the current to reach approximately 63.2 percent of its final value, after a steady voltage is applied. (2) In structural dynamics, the response of a structure to a transient load. (3) A quantity (T) defined by the expression $T = 1/2\pi f$ where f is the frequency of chopping of the radiation by a sine wave which causes the root-mean-square signal to decrease by 3 decibels from the signal for very slow chopping.

TIME CONSTANT, CIRCUIT. Circuit, time constant of a.

TIME-DELAY RELAY. A relay in which the energizing or de-energizing of the coil precedes movement of the armature by an appreciable and generally determinable interval.

TIME DILATATION. A principle of **relativity** that time slows down as an object approaches the speed of light. Time dilatation is one of the conclusions drawn from the general theory of relativity. It is sometimes referred to as the "clock paradox" in that a moving clock is theoretically slowed compared to a fixed clock in proportion to its speed. It provides that a space traveler's time would be of less duration than that elapsed on earth according to the relationship:

Space traveler's time

$$= \sqrt{1 - \frac{v^2}{c^2}} \times (\text{earth time}),$$

where v is the velocity of travel and c is the velocity of light. Time dilatation theoretic-

cally would permit a space crew traveling at near the velocity of light to return to the earth sensibly younger than their friends remaining on earth. The proposal has been made to obtain experimental confirmation of time dilatation by sending from the earth, on a return trip, a very accurate clock contained in a rocket.

TIME DIVISION. The process of propagating a plurality of information-bearing signals over a common medium, allocating a different time interval for the transmission of each signal.

TIME MODULATION. The modulation of a (pulsed) signal by another signal, commonly as applied in the measurement of distance by the interaction of a signal with its echo. Where the time interval between successive pulses is adjusted to a larger or smaller value proportional to some intelligence, the system is called "pulse time modulation." The measurement of such a time interval is termed "time demodulation."

TIME SHARING. Multiplexing.

TIME STANDARD. A highly reliable time reference used for the origin of a central timing system. One system in use consists of a crystal oscillator housed in a temperature controlled oven, beat against the WWV radio station (Bureau of Standard's time station) signal for control purposes.

TIME, STANDARD. Time as established by a nation or group of nations. A few of the smaller nations still use the local civil times of their individual capitals as standard everywhere within their borders. The larger nations employ a system on which the earth is divided into standard time zones. Each zone is 15° of longitude, or one hour of time, in width, with the center of each zone an integral number of hours east or west of Greenwich, England.

In Canada and the United States five standard time zones are employed. These are known as Atlantic (Maritime), Eastern, Central, Mountain, and Pacific, and the centers of each are 4, 5, 6, 7, and 8 hours west of Greenwich, respectively.

TIN. Metallic element. Symbol Sn. Atomic number 50.

TINY TIM ROCKET. A U.S. Navy solid propellant rocket. Tiny Tim was used as a booster for the **WAC Corporal** firings in 1945-46. The thrust of the Tiny Tim as a booster was increased from 30,000 pounds (for one second) to 50,000 pounds (for one half second). Tiny Tim was essentially a 1284 pound rocket with 160 pounds of propellant and an available payload of 590 pounds. It was 10½ feet in length, 11 inches in diameter and was to be used as an air-to-surface weapon. It was first used at Okinawa, but did not see extensive service.

TIP-OFF. The angular momentum acquired by a missile due to the action of gravity if its forward supports leave the launcher before the aft supports.

TIP RAKE. A geometrical characteristic of aerodynamic surfaces; the trailing edge tip is cut such that its angle with the missile center-line is less than the **Mach angle**.

TIP VORTEX. In aerodynamics, the vortex formed by air spilling over the wing tips from the area of high pressure below to the area of low pressure above the wings.

TITAN (SM-68). The intercontinental ballistic missile (ICBM) under manufacture by the Glenn Martin Company, for the Strategic Air Command. In 1956, Martin prepared a special assembly plant at Denver for the production of this missile. The official U.S. Air Force designation was the WS-107A-2. It carries a nuclear warhead; it has a range of 5500 nautical miles, and a speed of 15,000 m.p.h. It is launched vertically; it executes programmed roll to desired azimuth, and programmed pitch-over to desired flight attitude. Its length is 90 ft. (est.); diameter, 10 ft. (est.); and its launch weight is 200,000 lb. It has a two-stage airframe; its first-stage engine, liquid propellant, has a 300,000 lb. thrust, and its second-stage engine, a 60,000 lb. thrust. Its airframe is by the Glenn L. Martin Co.; its systems engineering by Ramo-Wooldridge; its propulsion system, by Aerojet-General; its guidance system, by American Bosch-Arma, Ramo-Wooldridge Corp. and Bell Telephone Laboratories; its nose cone, by Avco; its warhead, by the Atomic Energy Commission; its fuze by Sandia Corp.; and its support equipment by Aerojet-General. The guidance is

radio-inertial. (See **missile, guided**.) (See also illustration facing Page 442.)

TITANIUM. Metallic element. Symbol Ti. Atomic number 22.

Tl. Thallium.

Tm. Thulium.

TM. Tactical Missile. A **guided missile** used in tactical operations.

TM-61. Matador.

TM-76A. Mace.

TMB. David Taylor Model Basin; Washington, D.C.

T/O. Table of Organization.

TOMODROMIC COURSE. A course heading in such a direction as to make an intersection with some other course; an intercept course.

TONE. (1) A sound wave capable of exciting an auditory sensation having pitch. (2) A sound sensation having pitch.

TOPOGRAPHIC MAP. A map which presents the horizontal and vertical positions of the features represented; distinguished from a planimetric map by the addition of relief in measurable form. A topographic map usually shows the same features as a planimetric map, but uses contours or comparable symbols to show mountains, valleys, etc., and in the case of hydrographic charts, symbols and numbers to show depths of water.

TOPPING. In missile fueling, the procedure of continually adding to the amount of fuel or other volatile material in order to maintain a critical level. Liquid oxygen topping is a constant necessity in liquid-fueled missiles employing liquid oxygen as one of the propellants, because liquid oxygen evaporates at such a high rate that its continuous addition is necessary to maintain sufficient oxidizer for proper combustion. Liquid oxygen evaporates in large uninsulated containers at a rate of approximately 0.1% or more per minute.

TORNADO. Some thunderstorms, particularly the line-squall type, occasionally develop a violent whirl of air (or tornado) which extends down from the base of the cloud and

touches the earth. It often draws up into the cloud again and may strike some distance away or never reappear. Very low pressure prevails inside a tornado because of its great vorticity. Velocities of 200 to 300 mph are suspected in tornadoes.

TORQUE. (1) For a single particle the torque is the **moment** of the resultant force on the particle with respect to a particular origin. This is expressed by the vector relation $\mathbf{L} = \mathbf{r} \times \mathbf{F}$, where \mathbf{L} is the torque, \mathbf{r} is the position vector with respect to the origin, and \mathbf{F} is the resultant force. The torque is equal to the time rate of change of the moment of momentum. (2) For a rigid body the torque with respect to a set of axes is expressed by the relation

$$\mathbf{L} = \int \mathbf{r} \times \mathbf{F}_r dv,$$

where \mathbf{F}_r is the resultant force per unit volume due to external forces on the element dv and \mathbf{r} is the position vector of the volume element. (See **moment of force**.) For a rigid body undergoing free rotation about a single axis, the torque $\mathbf{L} = I\alpha$, where I is the moment of inertia and α is the angular acceleration.

TORQUE AMPLIFIER. A device possessing input and output shafts and supplying work to rotate the output shaft, without imposing any significant torque on the input shaft. The speed of the output shaft is equal or proportional to that of the input shaft, regardless of the load on the former.

TORSION. Twisting, or the resistance of a body to twisting (about an axis of symmetry).

TOTAL IMPULSE. Impulse, total.

TOTAL PRESSURE. In a moving fluid, the sum of the static pressure and dynamic pressure; in a stationary fluid, the static pressure. The total pressure is also the pressure measured at the stagnation point when a moving gas stream is brought to rest, and its kinetic energy is converted by an isentropic compression to the stagnation pressure.

TOTAL TEMPERATURE. The temperature resulting when a moving fluid is stopped at the point of measurement. It is that temperature which would be measured at the stagnation point if a gas stream were stopped with adiabatic compression from the flow condition

to the stagnation pressure. (See **normal shock wave**, **oblique shock wave** and **temperature**.)

TPR. The telescopic photographic recorder, an optical instrument manufactured by the Perkin-Elmer Corporation. It is a portable system with a 24-inch aperture, variable 100, 200 and 300-inch focal-length optics mounted on a M2A1 90mm antiaircraft artillery gun mount.

T.R. ROCKET. A British air-launched research rocket weighing 937 pounds. It was 11 feet in length, 18 inches in diameter and it was powered by rocket motor operating on hydrogen peroxide, methyl alcohol, **hydrazine hydrate** and water. It was capable of a velocity of 1000-1300 feet per second to a maximum range of 22 miles, following an air drop of 35,000 feet. It was begun as a project in 1946, which was expected to develop facts about transonic flight to be applied to piloted aircraft development.

TRACER. A foreign substance mixed with or attached to a given substance to enable the distribution or location of the latter to be determined subsequently. A physical tracer is one that is attached by purely physical means to the object being traced. A chemical tracer is one that has chemical properties which are similar to those of the substance being traced and with which it is mixed homogeneously. A radioactive tracer is a physical or chemical tracer having radioactivity as its distinctive property. An isotopic tracer is a radionuclide or an **allobar** used as a chemical tracer for the element with which it is isotopic.

TRACK COMMAND GUIDANCE. Guidance, track command.

TRACK-WHILE-SCAN. An electronic device used to detect a radar target, to compute its velocity, and to predict its future position without interfering with continuous radar scanning.

TRACKING. (1) The maintenance of proper frequency-relations in circuits designed to be simultaneously varied by gang operation. (2) The process of keeping radio beams set on a target. A motion given to the major lobe (see **lobe**, **major**) of an antenna, such that some pre-assigned moving target in space is always contained within the major lobe. (3)

The following of a groove by a phonograph needle. (4) The process of causing an index to follow the variation of a quantity by means of an **inverse feedback** (servo) **loop**.

TRACKING TELESCOPE. A telescope mounted on an automatic tracking mount to follow and photograph missiles in flight. These are frequently directed to their targets by radar data available for automatic positioning.

TRAFFIC-HANDLING CAPACITY. The ability of a guidance or weapon system simultaneously to control multiple missiles against one or more targets. For example, the active air-to-air homing guidance system is limited only by the number of missiles carried by the interceptor aircraft and the time available for launching the missiles. It is theoretically possible for the interceptor aircraft to launch more than one missile against the same target. In addition, it is possible for the interceptor aircraft to launch one missile against a target, break away, and launch another missile against a different target.

TRAILING EDGE. The major portion of the decay of a **pulse**.

TRAIN. In artillery terminology, to aim or point a device, such as a gun or radar set, in direction. Train means to traverse in a horizontal plane.

TRAINING DEVICE. A device for training personnel in the preflight checkout and flight operations of missiles; usually in electrical or mechanical **simulator**.

TRAJECTILE. Any object propelled by an external force into a free fall path.

TRAJECTORY. (1) The path of a body in motion. (2) The path of a missile from launch to impact or destruct. While there are two basic missile trajectories, **ballistic** and **aerodynamic** (including the "gravity-biased," aerodynamically-supported trajectory), there are a number of trajectories as defined by the path traveled. Some of these are: *Actual trajectory*, the standard trajectory as modified by the non-standard forces such as wind gusts, non-standard thrust, etc. *Aeroballistic trajectory*, a small portion of a trajectory assumed to be a straight line. *Ballistic trajectory*, a

missile trajectory which follows a symmetrical path from launch to impact. The powered flight portion is followed by a "pure" ballistic trajectory to reentry. *Glide trajectory*, a long-range missile trajectory in which the initial powered flight is followed by a reentry glide at optimum lift/drag ratio in the upper portions of the atmosphere. The glide portion may be accompanied by maneuvers to avoid counter-measures. (See **vehicle, glide**.) *Ideal trajectory*, the theoretical trajectory. *Powered flight trajectory*, in a ballistic, glide or skip missile trajectory, that part which includes flight while under power from booster, sustainer or vernier engines. During this period azimuth, elevation and velocity adjustments are made in terms of intended target coordinates. *Reference trajectory*, the Keplerian ellipse assuming no forces acting other than gravity. *Skip trajectory*, a long-range missile trajectory in which the initial powered flight is followed by a reentry skip and glide path using the upper portion of the atmosphere to support the missile aerodynamically on successive ballistic type reentries. (See **vehicle, skip**.) *Standard trajectory*, the trajectory computed for a particular body based upon a set of standard assumptions peculiar to that body. These specify that the body has a certain fixed mass, thrust, drag, aerodynamic response, etc., all of which are predictable before firing. The standard trajectory is an ideal trajectory embodying certain adjustments which bring it as close to actual as can be predicted beforehand. *Supported trajectory*, a non-ballistic trajectory which is affected by aerodynamic surfaces acting on the missile during non-powered flight. It is a trajectory in which lift must be considered. *Terminal trajectory*, the portion of the trajectory between reentry and impact. Reentry occurs at an altitude of approximately 250,000 ft. *Vacuum trajectory*, a ballistic trajectory involving no aerodynamic forces (i.e., lift and drag are zero). *Zero lift trajectory*, a ballistic trajectory in which drag may be present, but lift equals zero. (3) The simplified calculations of a trajectory can be summarized as follows: If v is the velocity of a body, t is the time, F is the thrust of the propelling power plant, θ is the inclination of the trajectory, g is the gravitational acceleration, m is the mass of the body, L the lift, and D the drag, the acceleration along the flight path is given by:

$$m \frac{dv}{dt} = F - D - mg \sin \theta$$

and the acceleration normal to the trajectory is:

$$m \frac{v^2}{R} = L - mg \cos \theta$$

Assuming the convention that altitude of a trajectory is represented by "y" and range by "x," the coordinates of a particle are given by:

$$x = \int_0^t v \cos \theta dt$$

$$y = \int_0^t v \sin \theta dt$$

Thus, the general trajectory problem is theoretically capable of solution. However, the actual solution by integration of these equations is complicated. The complications arise from the varying mass, lift and drag coefficients which must be included. Approximate methods of quick estimation are available, but these also use higher mathematics. Ordinarily the exact solution is carried out by **differential analyzers** or numerical integration on **automatic computers**. For guided missiles where angular accelerations are developed as part of the guidance process, the computations become even more complicated. Rocket trajectories are described by the two differential equations given above. The thrust of a rocket is generally uniform and is given by:

$$F = \frac{m_p}{t_p} c,$$

where m_p is that total mass of propellant used, t_p is the duration of burning, and c is the exhaust velocity, or since $c = I_{sp}g$:

$$F = \frac{m_p}{t_p} I_{sp}g$$

However, the mass of the rocket is not constant but is decreasing at the rate of m_p/t_p per second, so at any time:

$$m = m_o - \frac{m_p}{t_p} t$$

and the changing value must be substituted as the time of flight changes. The following equations are helpful in evaluating the performance of a rocket missile:

Range

$$\text{Range} = x = \frac{2CR}{1-C} \sqrt{1 + h_{co}/CR}$$

where R is the radius of the earth, h_{co} is the cut-off altitude, and C is a complex function given by:

$$C = \frac{v_{co}^2}{2gR} \left(1 + \frac{h_{co}}{R} \right).$$

A good first order approximate equation for range is given by:

$$x \approx \frac{v_{co}^2}{g} + h_{co}$$

Altitude at cut-off

$$h_{co} = g(I_{sp})^2 \frac{n-1}{an} \left[1 - \frac{\ln n}{n-1} - \frac{1}{2} \frac{n-1}{an} \right]$$

where h is the altitude, g is the acceleration of gravity, I_{sp} is the specific impulse, n is the loaded weight/empty weight, and a is the thrust/loaded weight (i.e., initial acceleration).

Peak Altitude

$$h_p = g(I_{sp})^2 \left[\frac{(\ln n)^2}{2} = \frac{1}{a} \left(\ln n - \frac{n-1}{n} \right) \right]$$

Velocity at cut-off

$$v_{co} = g I_{sp} \left(\ln n - \frac{n-1}{an} \right)$$

Note the above equations assume a vertical powered climb. A projectile is assumed to follow the equations given below:

$$x = vt \cos \beta$$

$$y = vt \sin \beta - \frac{1}{2}gt^2$$

$$t_f = \frac{2v \sin \beta}{g}$$

TRAJECTORY DATA. Measurements relating to the flight path of a missile. They include position, velocity, acceleration, trajectory angles and attitude data. Trajectory data are obtained from **radars**, **phototheodolites**, **ballistic cameras**, **telemetry devices**, and **Doppler position instruments**, etc.

TRAJECTORY OF AIR PARCELS. A parcel of air located in a given pressure field will move with the gradient wind of the field (assuming steady flow). At the end of a few hours, the parcel will locate in some new re-

gion where it has been carried by the wind. If, however, the pressure field and therefore the wind is changing, the parcel will not move into a position indicated by the existing gradient flow. It will follow a trajectory or path dictated by successive gradient directions and velocities as indicated by synoptic charts. An approximation to its trajectory can be had by extrapolating the parcel's indicated movement for as small a time interval as practicable (usually 3 or 6 hours between synoptic charts) using successive synoptic charts. The average of the velocity vectors at the beginning and the end of a given time interval would be taken as the true velocity and direction of the parcel over that time interval. Obviously, the smaller the time interval, the more accurate the trajectory. One of the charts may be a prognostic chart for computing future trajectories. Air trajectories are valuable in estimating the influence the earth will have on air as it flows over varied earth surfaces.

TRAJECTORY PHASES. (Of a missile flight). (1) *Launch Phase*: Normally that portion of the test from launch to booster burnout, in the case of aerodynamic missiles; or from launch to motor burnout, in the case of ballistic missiles. (Note: this definition may vary from missile to missile and must be defined for each missile.) (2) *Mid-Course Phase*: From end of launch phase to beginning of terminal phase. (3) *Terminal Phase*: That portion of the test from initiation of terminal dive or recovery, in the case of aerodynamic missiles, or from reentry (approximately 100,000 feet in altitude), in the case of ballistic missiles, to termination of test.

TRANSADMITTANCE. The ratio of the current in one part of an electrical system to the electromotive force or potential difference applied at some other point in the system. The grid-plate transadmittance of a vacuum tube is an example.

TRANSCEIVER. A portable device which can perform both the functions of transmission and reception of radio communications.

TRANSCONDUCTANCE. Mutual conductance. A conductance (I/R or I/E) relating input and output. As most commonly used, the interelectrode transconductance between the control grid and the plate. At low fre-

quencies, transconductance is the slope of the control-grid-to-plate transfer characteristic. More generally, the transconductance may be defined as the ratio of the change in the current flowing from one pair of terminals, these terminals being short-circuited, to the change in the potential difference across another pair of terminals. All changes are assumed small.

TRANSCRIBER. (1) A device for converting coded information back to its original state. (2) In data reduction equipment, a device for transferring data from one form to another. For example, magnetic tape data might be transcribed to IBM punched card form. Such equipment may transfer data from the computer language to plain text or the reverse.

TRANSDUCER. (1) A device actuated by power from one system and supplying power in the same or any other form to a second system. These systems may be electrical, mechanical, or acoustical. (2) a pickup or end organ in a telemetering system. (See *beacon*.)

TRANSDUCER, ELECTROACOUSTIC. A transducer for receiving waves from an electric system and delivering waves to an acoustic system, or vice versa.

TRANSDUCER GAIN. The ratio of the power that a transducer delivers to its specified load under specific operating conditions to the available power of the specified source. If the input and/or output power consists of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting should be specified. This gain is usually expressed in decibels.

TRANSFER CHARACTERISTIC. (1) In electron tubes, a relation, usually shown by a graph, between the voltage of one electrode and the current to another electrode, all other electrode voltages being maintained constant. (2) In a transducer or servo system, a mathematical expression relating the input to the output; usually in terms of a differential equation or a Laplace transform. (See *transfer function*.)

TRANSFER ELLIPSE. In satellite launching, an intermediate coasting trajectory (seg-

ment of an ellipse), designed to bring the vehicle into the proper position for the injection stage firing. (2) In astronautics, a flight path used to bring a space craft from one circular orbit to another. The computation of the transfer ellipse is generally aimed at obtaining the one requiring a minimum of energy (i.e., fuel).

TRANSFER FUNCTION. (1) A mathematical expression which expresses the relationship between the outgoing and incoming signals of a process, control element, system, device, etc. Shaping, restraints, band-pass and other characteristics are defined. A common expression for the transfer function is the Laplace transform of the network output to the Laplace transform of the network input, with all initial conditions set equal to zero. The expression **transfer characteristic** can be used to refer either to the transfer function or the frequency-response when the initial conditions are all equal to zero.

TRANSFER ORBIT. Orbit, transfer.

TRANSFER ROOM. The transfer room below the erection area is connected to the control building by an underground cableway. It houses the relay racks, terminal boards, and other equipment necessary to route cables from the test stand to the control building.

TRANSFER VALVE. An electrohydraulic or electromechanical device used to control the power circuit of a servo by means of an electrical signal. (See **Valve, three-way; valve, four-way.**)

TRANSFORM. (1) If A , B , X are three matrices or three elements of a group, then $B = X^{-1}AX$ is the transform of A by X and A , B are conjugate to each other. The complete set of group elements which are conjugate to each other form a class of the group. (2) An integral equation of the first kind,

$$g(z) = \int K(x,z)f(x)dx$$

is called the transform of $f(x)$. Special cases are the Euler, Fourier, Laplace, Hankel, Mellin, etc., transforms.

TRANSFORMER. A device for transferring electric energy from a circuit to another by magnetic induction, usually with a change of

voltage. There are no moving parts, nor is there any electrical connection of the two circuits (except in the case of the auto-transformer); the energy is transferred through magnetic linkage. Regardless of the voltage, the energy supply circuit is termed the primary, and the energy receiving circuit the secondary.

TRANSIENT. (1) A transitory disturbance in a dynamic system. (2) That part of the forced oscillation of a linear system which decays more or less rapidly after the imposition of the force; to be distinguished from the **steady state**. (3) The non-permanent terms in the response of an electric network to a stimulus. In some circuits the form or presence of these is not significant, but in other situations they must be anticipated and carefully controlled to avoid unsatisfactory performance of the equipment.

TRANSIENT RESPONSE. The response of an acoustical system to a suddenly impressed force or pressure.

TRANSIENT STATE. A condition in a dynamic system which implies a temporarily abnormal or erratic behavior of a variable such as speed, temperature, pressure, etc. Contrast **steady state** in which the variable is either held at a constant value or else changes uniformly with time.

TRANSISTOR. The transistor is an electronic device for amplification and/or control which consists of a semiconducting material to which contact is made by two or more electrodes which are usually metal points or metal surfaces soldered to the semiconductor. The transistor is capable of performing many of the functions filled by the **electron tube**. Although its operating characteristics depend on temperature, the transistor has many advantages relative to the vacuum tube since it requires no heater (or filament) current, is small and light weight, can be made mechanically rigid and long lasting, and operates at low voltages with comparatively high efficiencies.

Semiconductors are materials which have electrical conduction properties much poorer than good conductors but, on the other hand, much better than materials classed as insulators. The most common semiconductors in use at present for transistors are **germanium** and **silicon**. For use in transistors, the semi-

conductor materials must be purified to a phenomenal degree. The need for single crystals of these semiconducting materials in this application has led to the development of entirely new purification methods as well as novel means for detecting impurities. Germanium and silicon are located in Group IV of the periodic table (see **chemical composition**). In a perfect crystal state the four **valence** electrons of an atom of germanium (or silicon) form covalent bonds (see **valence**) with neighboring atoms in which the two electrons in each bond are shared equally with the two atoms at its ends. This bond structure is three dimensional, but the action is indicated in a two dimensional form in Fig. 1. Absorp-

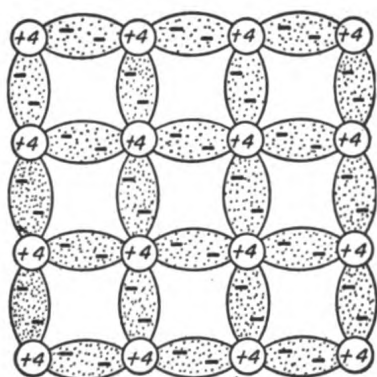


Fig. 1. Representation of electron-pair bond structure in silicon or germanium.

tion of energy either as a result of light or heat will cause rupture of a covalent bond releasing an electron and leaving a defect, or "hole," in the otherwise periodic structure. For germanium an absorbed energy of 0.72 **electron volts** will release an electron from the bond while 1.12 electron volts is required for the same effect in silicon. Once released, the electron can move about the crystal with considerable freedom. Furthermore, it is also possible for an electron in a covalent bond adjacent to the bond which has just lost an electron to jump into the hole, leaving an electron deficit in the bond which was vacated. By this mechanism it is possible for a hole to move through the crystal at the same time free electrons move. In metals, electric conduction takes place by means of the valence electrons of the metallic atoms which are free to move throughout the metal. In semiconductors where, however, there are far fewer free electrons to act as charge carriers, the conduc-

tion process occurs through the simultaneous motion of electrons and holes. The hole concept represents a means of describing an incomplete assemblage of electrons and with this fact understood, holes may be considered to have a positive charge equal in magnitude to that possessed by an electron as well as an appropriate mass. These two properties enable calculation of the hole movement to be expected in the presence of **electric and magnetic fields**. The conductivity (σ mho-cm.⁻¹) of a semiconductor can be expressed in terms of the density of holes (p per cubic centimeter) and of electrons (n per cubic centimeter) and the electron and hole mobilities (μ_n and μ_p -cm./sec. per volt/cm.), the latter being the **drift velocity** in a unit electric field. The result is

$$\sigma = q(n\mu_n + p\mu_p)$$

where q is the electron charge. It is clear that an increase in either hole or electron concentration will change the conductivity of the semiconductor although the two densities have different numerical effects due to the difference between hole and electron mobilities ($\mu_p = 1700$, $\mu_n = 3600$ cm./sec. per volt/cm. for germanium; $\mu_p = 400$, $\mu_n = 1200$ cm./sec. per volt/cm. for silicon). In a pure sample of a semiconductor the holes and electrons are produced in pairs so that the two densities are equal (n_i). The conductivity that results for such an intrinsic semiconductor is called the intrinsic conductivity (σ_i). It is expressible as $\sigma = qn_i(\mu_n + \mu_p)$.

Transistors depend for their operation on either an excess of free electrons or a deficit of electrons (excess of holes) in covalent bonds. A semiconductor in which the first condition obtains is spoken of as an *n* type material (excess of negative carriers) whereas one in which the second situation exists is referred to as a *p* type semiconductor (excess of positive carriers). An excess of electrons or holes is produced by adding minute amounts of impurities to an intrinsic semiconductor. Elements from Group V of the periodic table have five valence electrons. If atoms of a Group V element (phosphorus, arsenic, antimony, bismuth) are added to an otherwise pure sample of germanium (or silicon), four of the five valence electrons of the impurity atom are shared in the covalent bonds formed with neighboring germanium atoms. The fifth valence electron is free to move throughout

the crystal. An excess of electrons is thus created by the addition of the impurities; n type germanium now exists. The elements capable of effecting this condition are called donor elements. Antimony and arsenic are typical donor elements for germanium and silicon transistors. Impurities from Group III of the periodic table (boron, aluminum, gallium, indium) produce corresponding effects when added to a Group IV semiconductor. Since the Group III elements have only three valence electrons, only three germanium atoms can be bonded to the impurity atom by sharing of electrons. Since the impurity atom occupies a position in the crystal structure normally filled by a germanium atom (which has four bonds), the addition of the impurity will result in the deficiency of one electron in a germanium bond in the proximity of the impurity. A hole has thus been created and p type germanium has resulted. Elements producing this effect are called acceptor elements. Typical acceptors for germanium and silicon transistors are aluminum and gallium. It should be noted that if both donor and acceptor elements are present, the material will exhibit the properties of n or p type material depending on whether the electron density exceeds the hole density or vice versa. If the two densities are equal, the material will behave as an intrinsic semiconductor unless the impurity concentration is quite high.

A rod of single crystal germanium with alternating n and p type regions can be obtained by adding suitable impurities to the molten germanium as the rod is withdrawn from the crucible used for melting in the process of forming a crystal. If donor and acceptor impurities are added in succession, it is possible to obtain n-p-n and p-n-p configurations along the rod. By this method, there will be a region created where n type conductivity predominates followed by one where p type prevails in the same germanium crystal. A p-n junction will be produced where the two regions of different conductivity come together. In contrast with these so-called grown junctions, it is also possible to obtain a pair of p-n junctions for transistor action by starting with a thin wafer of germanium of a prescribed conductivity type and fusing impurity regions of the opposite type in localized areas on opposite sides of the wafer, leaving a thin section of the original material in the center of the wafer cross section. Junctions

prepared in this manner are called fused alloy junctions.

Before considering the transistor itself which consists of a combination of two p-n junctions (arranged as p-n-p or n-p-n), it is of interest to examine conditions which exist in a single p-n junction. Fig. 2 shows a p-n

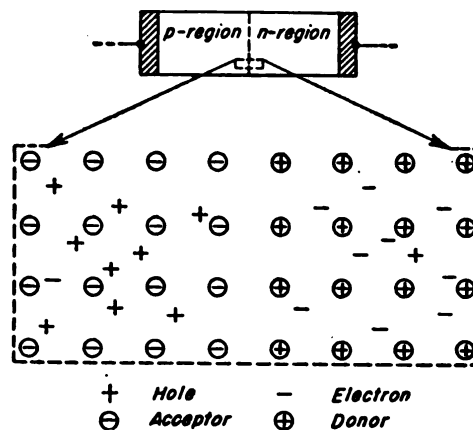


Fig. 2. Schematic representation of a p-n junction showing acceptor and donor atoms and free electrons and holes.

junction including the acceptor and donor atoms in the n and p regions, respectively, as well as the holes and electrons which are free to move. It noted that even in the n type region there are some holes, although a relatively small number, and a corresponding situation exists in the p type region. These carriers, which are of opposite sign to the intended or majority carriers, come into existence due to the rupture of covalent bonds as the result of the thermal energy of the atoms and are called minority carriers. If no external potential difference is applied across the electrodes shown in the figure, an equilibrium condition will be established wherein no electrons or holes exist in the immediate vicinity of the junction. Because of the arrangement of the fixed, oppositely charged donor and acceptor atoms at the boundary of the n and p type materials, an electric dipole is formed yielding an appropriate electric field and corresponding difference of potential across the boundary between the two regions. If a potential difference of suitable magnitude is applied to the junction such that the electrode connected to the p region is positive with respect to the other electrode (producing a forward biased junction), the majority carriers in each region will be forced to flow

across the junction, the net current flow being the sum of the current carried by the holes plus that carried by the electrons. The respective densities of holes and electrons (p and n) are determined by the impurity concentrations in the p and n type regions. By suitable control of the relative amounts of impurities used, the current that flows across the junction in the forward biased condition can be arranged to be composed principally of holes, principally of electrons, or some suitable combination of both. In any event, the flow of conventional current is into the p region and out of the n region. If the polarity of the external potential difference is reversed, the only current that will flow into the terminals of the device will be that contributed by the thermally generated minority carriers which will be a small one indeed compared to the current obtained in the forward biased condition. This current rapidly reaches a limiting value called the saturation current as the reverse bias voltage across the device is increased. Because the current that flows is practically independent of the applied voltage beyond a certain minimum value, the impedance of the reversed bias junction is extremely high. By contrast, the impedance in the forward biased direction is very low.

A transistor of the n - p - n type is shown diagrammatically in Fig. 3a. A small p type

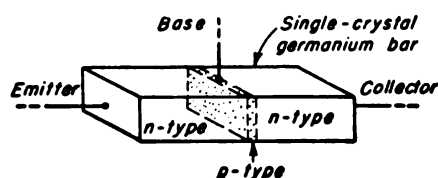


Fig. 3a. n - p - n junction transistor.

region is contained between two n type regions and connections are made to all three regions. The terminals are labelled emitter, base, and collector for reasons that will become apparent shortly. In normal operation as an amplifier, the emitter to base junction is forward biased and the collector to base junction is reverse bias. The emitter to base impedance is low whereas the collector to base impedance is high for reasons considered above. Fig. 3b indicates the current flow existing across the junctions. A small saturation current composed of holes and electrons flows across the collector junction; this current is not controlled by the emitter. On the other hand, the

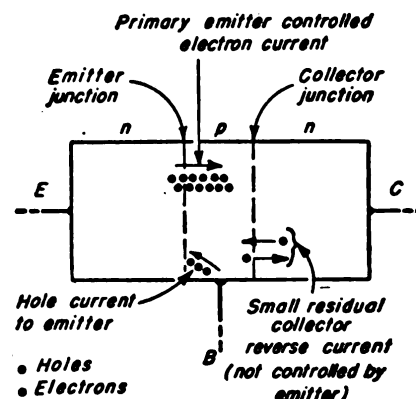


Fig. 3b. Current flow across junctions in transistor.

electrons coming into the base from the emitter due to the forward biased emitter-base junction represent minority carriers for the collector-base junction and for a thin enough base section these carriers pass through the base layer, cross the collector junction, and contribute to the collector current. A hole current from the base region also flows across the emitter junction to add to the electron current in producing the total emitter current. The essential action is the emitting of carriers from the emitter region and the collection of practically all of these carriers by the collector. By proper design of the impurity concentrations and base layer width, the ratio of the emitter electron current to the emitter-base hole current can be made very large (values in the order of 100 are attainable). If the input of the amplifier is taken to be between base and emitter with the output taken between collector and emitter, then the input current is the small base-emitter hole current and the output current is the emitter-collector electron current. A significant current gain is thus achieved. If, on the other hand, the input current is applied between emitter and base and the output circuit is connected between collector and base, then no current gain results since the current entering the emitter terminal (sum of hole and electron currents) is only slightly less than the current leaving the collector (electron current from emitter plus collector saturation current). This latter amplifier connection does permit a voltage gain, however, because the high output impedance permits use of a large load resistor through which a current essentially equal to the input current can flow. In contrast with vacuum tubes, transistors con-

trol output currents as a result of changes in input current rather than input voltage.

Another type of transistor is shown in Fig. 4. This device is known as a point contact transistor. Rectifying action occurs at both emitter and collector contacts with the germanium surface. A p-n barrier exists at both

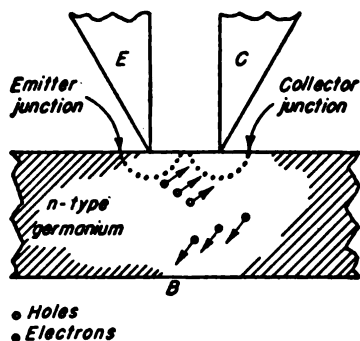


Fig. 4. Schematic diagram of point-contact transistor.

contacts as shown by the dotted lines as a result of contact between the bulk n type germanium and p type inserts. The base connection is made through a large area contact at the bottom of the material. If the emitter is forward biased and the collector reverse biased with respect to the base, holes are injected from the p region at the emitter into the n type region and are swept to the collector electrode under the influence of the electric field between collector and base. In addition to the high impedance of the collector circuit which permits voltage gain with the device, there is also a current gain effected. As a result of the current gain, the input resistance of a point contact transistor amplifier can become negative permitting relaxation oscillations under certain conditions.

Fig. 5 illustrates a p-n junction photocell.

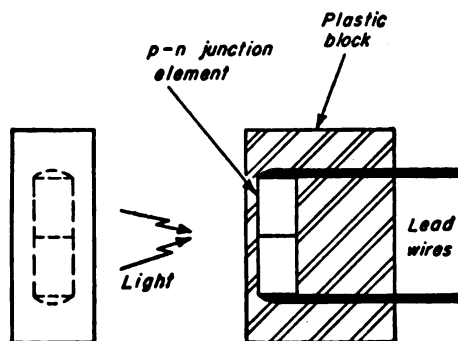


Fig. 5. p-n junction photocell; left, front view; right, side section drawing of element and capsule.

In operation, the p-n junction is reverse biased, being connected in series with a load resistor across which the desired output voltage is to be developed. When light falls upon the germanium surface, hole-electron pairs are created by the photoelectric process. The minority carriers diffuse across the p-n junction and produce an increase of current in the load resistor. The current increase is dependent upon the light energy absorbed.

Several advantages of the transistor over the vacuum tube have already been stated. A significant property of the transistor which has no counterpart in vacuum tubes is the availability of devices of opposite conductivity types, for example, n-p-n and p-n-p transistors. If two of these devices are made to have identical characteristics except for their conductivity types, it is found that they are symmetrical counterparts of one another in that one has positive currents and voltages whereas the other has identical negative characteristics. One set of collector voltage-current characteristics appears in the first quadrant while the other has odd function symmetry being located in the third quadrant. Fig. 6 shows typical collector characteristics.

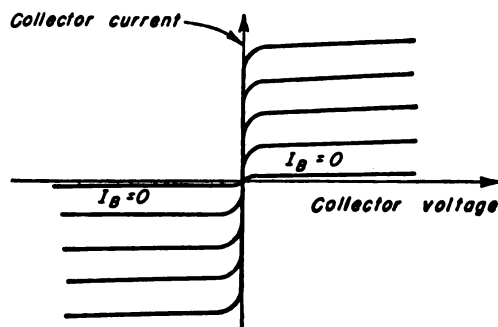


Fig. 6. Typical collector characteristics showing complementary symmetry property of n-p-n and p-n-p junction transistors.

This property is called complementary symmetry. It is of advantage in arranging for biasing currents and in providing certain circuit functions.

TRANSISTOR CIRCUITS. Transistors may be combined with sources of power and passive elements (resistors, inductors, and capacitors) to form transistor circuits of many forms which are used for the generation, amplification, shaping, and control of electrical signals. Many transistor circuits are similar

in form to vacuum tube arrangements designed to perform corresponding functions, but, on the other hand, the unusual properties of transistors also lead to circuit arrangements which have no vacuum tube counterparts. Significant differences between vacuum tubes and transistors make the latter far more attractive in applications where the principal objective is the amplification of low level signals where comparatively little power is associated with the signal itself, the combining and processing of signals as required in electrical computation, and the switching of electrical signals to various paths in accordance with appropriate command signals. The fact that extremely low power is required for a transistor to effect these functions combined with its property of much smaller size and weight than a vacuum tube make possible the fabrication of electronic circuits to perform very complicated operations in a small space with low power consumption. The availability of n-p-n and p-n-p transistors which have the principal charge carriers of opposite sign (see complementary symmetry under **transistors**) leads to advantages in cascading transistor amplifiers or data processing circuits on a d-c basis and to simplifications in attaining push pull operation with its concomitant benefits.

One fundamental difference between vacuum tubes and transistors is the manner in which control of the output current is effected. Vacuum tubes are voltage operated devices, i.e., the plate current is controlled by the voltage impressed between the grid and cathode. The collector current, the usual out-

put current in a transistor, on the other hand, is controlled by the flow of current between base and emitter. The potential difference across the emitter-base junction is a non-linear function of the junction current. As a consequence, to avoid introducing amplitude **distortion**, the input signal current must be furnished from a high **impedance** source. This factor alone often results in differences between vacuum tube circuits and the corresponding transistor versions.

As with vacuum tube circuits, when a transistor is employed in conjunction with other circuit elements, a suitable combination of operating parameters must be chosen to establish a quiescent operating point about which the input signal will cause variations in the various electrode currents. The operating point is established by providing appropriate sources of potential in series with resistors in order to obtain the desired steady emitter, base, and collector currents referred to as *bias* currents.

Operation of transistors may take place in a linear or non-linear fashion (see **electron tube circuits**) depending on the amplitude of the input current. When the variations in the input current are small (defined in the same sense as "small signal" operation with electron tube circuits), **equivalent circuits** may be used for the calculation of the changes in currents about the operating point. Fig. 1(a) illustrates common symbols for the p-n-p and n-p-n transistors. Emitter, base, and collector terminals are indicated by *e*, *b*, and *c*, respectively. Fig. 1(b) shows a p-n-p unit

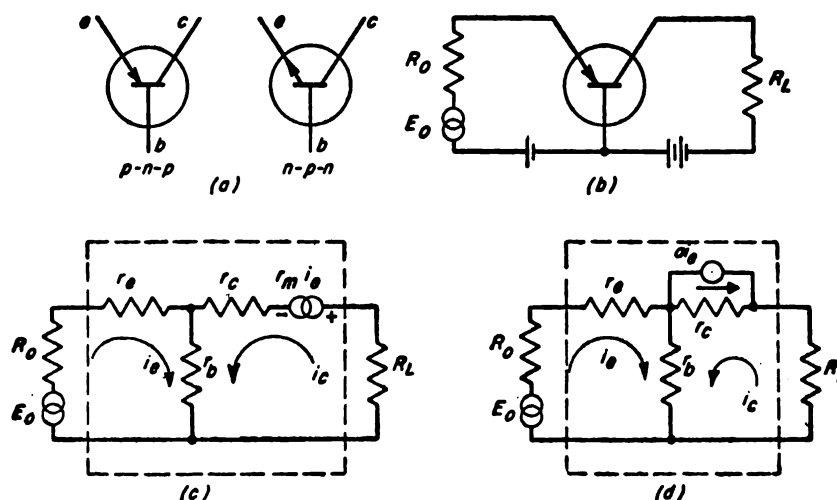
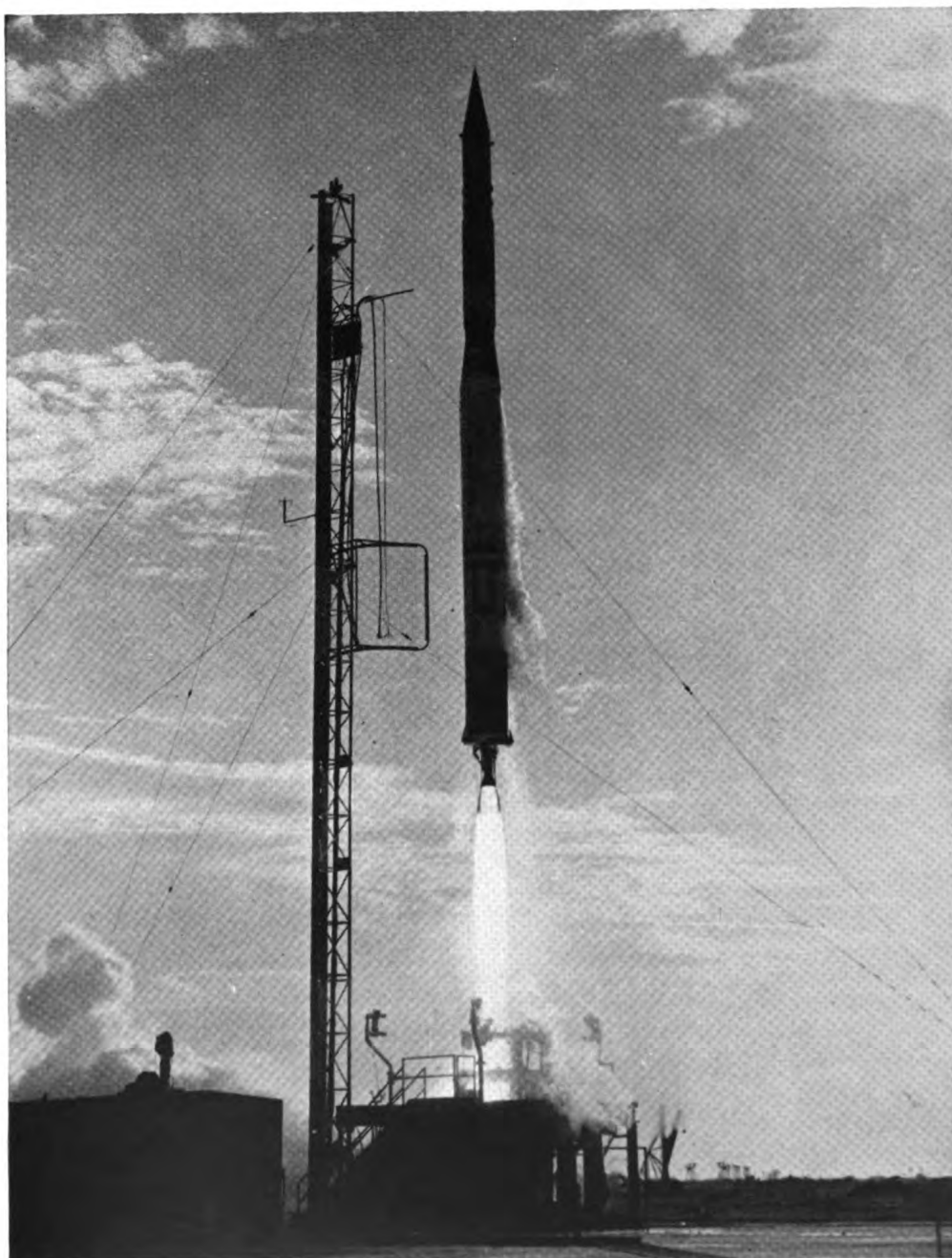


Fig. 1. (a) symbols for transistor; (b) common base amplifier circuit; (c) and (d) two transistor T equivalent circuits.



Successful firing of VANGUARD I satellite rocket. (*U.S. Navy Photograph*)

connected in a common base amplifier circuit, and Figs. 1(c) and 1(d) indicate (in the dashed outline) one form of equivalent circuit that may be used to compute incremental changes in transistor currents. The representation is spoken of as the T equivalent circuit, and the parameters are defined in terms of the steady emitter-base and collector-base potential differences and currents (V_e , V_c , I_e , and I_c) as follows:

Base resistance,

$$r_b = \left. \frac{\partial V_e}{\partial I_e} \right|_{I_c \text{ constant}}$$

Emitter resistance,

$$r_e = \left. \frac{\partial V_e}{\partial I_e} \right|_{I_c \text{ constant}} - \left. \frac{\partial V_c}{\partial I_c} \right|_{I_e \text{ constant}}$$

Collector resistance,

$$r_c = \left. \frac{\partial V_c}{\partial I_c} \right|_{I_e \text{ constant}} - \left. \frac{\partial V_e}{\partial I_e} \right|_{I_c \text{ constant}}$$

Mutual resistance,

$$r_m = \left. \frac{\partial V_c}{\partial I_e} \right|_{I_c \text{ constant}} - \left. \frac{\partial V_e}{\partial I_c} \right|_{I_e \text{ constant}}$$

$$a = \frac{r_m}{r_c}$$

The partial derivatives appearing in the above expressions may be determined from suitable graphs of the parameters V_e , V_c , I_e , and I_c . The collector-emitter short circuit current amplification factor α_{ce} , or simply α , is defined as

$$\alpha = \alpha_{ce} = \left. \frac{\partial I_c}{\partial I_e} \right|_{V_{cb} \text{ constant}}$$

This quantity may also be expressed in terms of r_m , r_b , and r_c as

$$\alpha = \alpha_{ce} = \frac{r_m + r_b}{r_c + r_b}$$

For a junction transistor, r_m and r_c are very much larger than r_b so that

$$\alpha = \alpha_{ce} \doteq \frac{r_m}{r_c} = a.$$

For this reason a and α are often used interchangeably in the equivalent circuits of Figs. 1(c) and (d). Another quantity of interest is the collector-base short circuit current amplification factor α_{cb} defined as

$$\alpha_{cb} = \left. \frac{\partial I_c}{\partial I_b} \right|_{V_{ce} \text{ constant}}$$

For a junction transistor the following approximate relation is valid

$$\alpha_{cb} = \frac{a}{1-a} \doteq \frac{\alpha}{1-\alpha}.$$

The quantity α_{cb} appears in the equivalent T circuit for the common emitter connection. Fig. 2 indicates the equivalence for this arrangement. It is to be noted that the values of the various parameters in the equivalent circuits vary with the electrode currents as well as with frequency. The circuits presented are valid only at low frequencies. There are effects which occur at high frequencies which require assigning a frequency dependence to α as well as the introduction of capacitors across various elements. Typical low frequency values of r_e and r_m are in megohms; of r_b , several hundred to a thousand ohms; of r_c , less than one hundred ohms; and of α and α_{cb} , 0.98 to 0.99 and 50 to 100, respectively.

There are several forms of equivalent circuits that are used to represent transistor small signal operation in addition to the T network form just described. Another representation that finds frequent use is one employing the so-called hybrid parameters. The parameters are "hybrid" in the sense that they do not all have the same dimensions. Fig. 3 indicates the equivalent circuit for the common emitter connected transistor using these parameters. The base-emitter circuit is represented by an impedance h_{11e} in series with

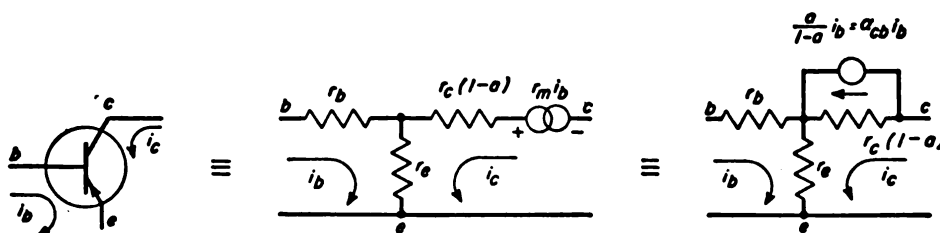


FIG. 2. Common emitter connection and its equivalent circuits.

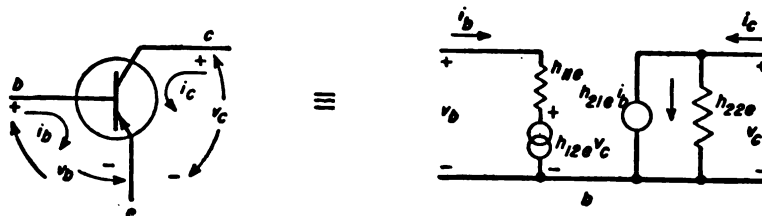


Fig. 3. Hybrid parameter equivalent circuit for common emitter connection.

a voltage generator. The collector-emitter circuit is represented by an admittance h_{12e} in parallel with a current generator. The parameters are defined in terms of static currents and voltages as follows:

h_{11e} = input impedance (short circuit across output terminals)

$$= \left. \frac{\partial V_{be}}{\partial I_b} \right|_{V_{ce} \text{ constant}}$$

h_{22e} = output admittance (no connection across input terminals)

$$= \left. \frac{\partial I_c}{\partial V_{ce}} \right|_{I_b \text{ constant}}$$

h_{12e} = reverse open circuit voltage amplification factor

$$= \left. \frac{\partial V_{be}}{\partial V_{ce}} \right|_{I_b \text{ constant}}$$

h_{21e} = forward short circuit current amplification factor

$$= \left. \frac{\partial I_c}{\partial I_b} \right|_{V_{ce} \text{ constant}} = \alpha_{cb}.$$

These parameters may be defined for any form of transistor connection. The subscript e denotes common emitter connection; a corresponding labelling is used to distinguish the parameters for other connections.

In the **transistor** article, the current flow across a reversed bias p-n junction was discussed, and it was indicated that the components of current are oppositely flowing minority carrier holes and electrons which have resulted from thermally generated hole-

electron pairs in the n type and p type regions. It is expected, therefore, that the saturation current will be highly temperature dependent. This anticipated behavior has been found to occur in practice. The variation of collector saturation current (that obtained with zero emitter current) with temperature is one serious problem associated with transistor operation. Another major contributor to temperature problems is the variation of the **conductance** between base and emitter as the temperature is changed. The collector current may be stabilized with respect to both of these temperature effects by the use of **feedback** circuits such as those shown in Fig. 4. Fig. 4(a) indicates the use of a resistor in series with the emitter terminal to effect the feedback whereas Fig. 4(b) shows a connection between the collector and base terminals to accomplish a similar objective. Fig. 4(c) shows an amplifier with compensation of both types included. A bypass capacitor would normally be used across the resistor in series with the emitter to avoid loss of gain at the frequency of the signal to be amplified.

Transistors are used with small signal inputs in all of the applications where vacuum tubes have been introduced. In the **amplifier** article considerable attention is given to the use of transistors in various circuits designed to perform amplification. Transistors may also be used as **reactance tubes**, modulators, and detectors in circuits quite similar to those using vacuum tubes. For pulse applications transistors have great appeal to circuit designers. Point contact transistors, for ex-

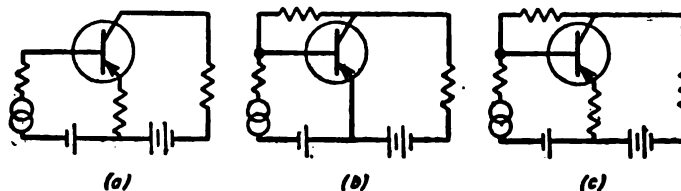


Fig. 4. Temperature compensation arrangements for stabilization of collector current: (a) emitter feedback; (b) collector to base feedback; (c) combination of emitter and collector to base feedback.

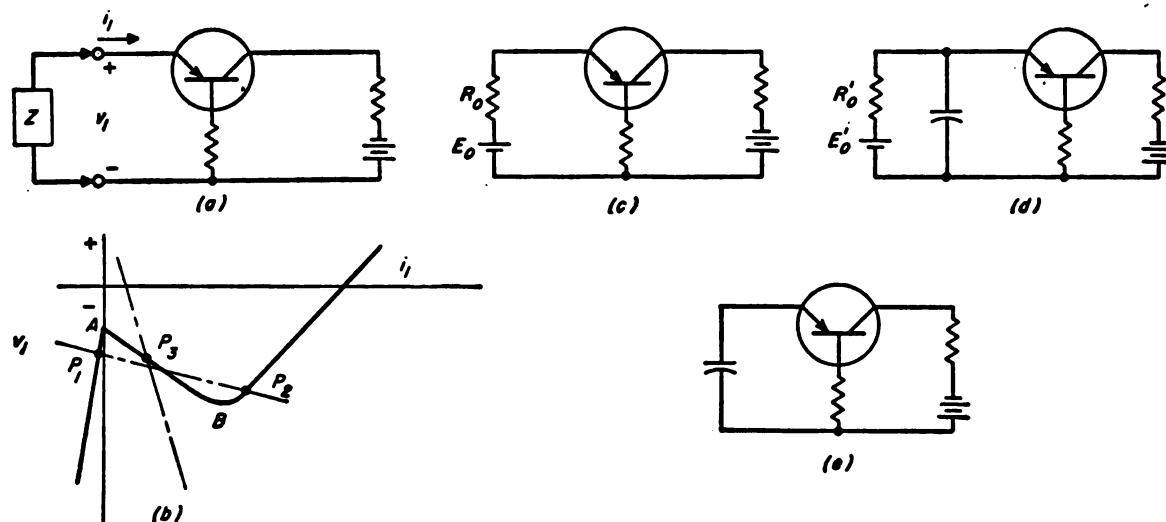


Fig. 5. (a) Generalized point contact transistor circuit; (b) input volt-ampere characteristic; (c) bistable multivibrator; (d) monostable multivibrator; (e) stable multivibrator.

ample, with current gains greater than unity, provide a negative resistance characteristic which enables construction of **relaxation oscillators** with one transistor. Fig. 5(a) shows the general form of a trigger circuit (see **electron tube circuits**) employing a point contact transistor. The form of impedance Z presented to the transistor determines the circuit behavior that results. Fig. 5(b) shows the volt-ampere characteristic at the input terminals of the device. The essential characteristic for trigger circuit operation is the negative resistance portion between A and B. If the figure of 5(c) is employed with the elements E_0 and R_0 chosen to produce a **load line** intersecting the volt-ampere characteristic in two places, say at P_1 and P_2 , then there will be two stable states of operation for the circuit at these two points. A trigger pulse of sufficient amplitude and polarity will cause the circuit to switch from one state to the other, yielding the characteristics of a bistable multivibrator. Choice of E'_0 and R'_0 so that the intersection of the load line occurs at a point between A and B, such as P_3 , results in an astable multivibrator operation from the circuit of Fig. 5(d). Finally, the use of a capacitor alone for Z , as in Fig. 5(e), yields monostable operation.

A form of junction transistor exists in which current gains greater than unity can be achieved in the grounded base connection. The device, called a hook multiplier transistor and shown in Fig. 6(a), consists of an ordinary n-p-n or p-n-p transistor with another p-n

junction added in the collector region. The resulting structure, a n-p-n-p or p-n-p-n tetra-rode transistor, has a "hook" shaped potential gradient distribution which permits carrier multiplication and a current gain (α) greater than unity, as in point contact transistors. Fig. 6(b) illustrates how the same characteristics may be obtained by connection of two ordinary triode junction transistors.

Junction transistors may be used in multivibrators, blocking oscillators, and similar pulse circuits in essentially the same manner in which vacuum tubes are used. The electrode voltages and currents will have different values, but in many situations the circuit arrangement of the components will be the same. There is a fundamental property of transistors, however, which may require attention when the operating point is subject to large excursions. For large signal applications the operating range of transistors is divided into three parts. Region I, where the emitter and collector junctions are both reverse biased, is called collector current cutoff or collector voltage saturation. Region II, called the active region, is the normal operating condition of emitter junction forward biased and collector junction reverse biased. Region III, with both junctions forward biased, is called collector current saturation or collector voltage cutoff. In pulse circuits the operating point of a transistor is frequently called upon to move from region I to region III, and vice versa. It is found that it takes considerably longer to switch from region III to I than from

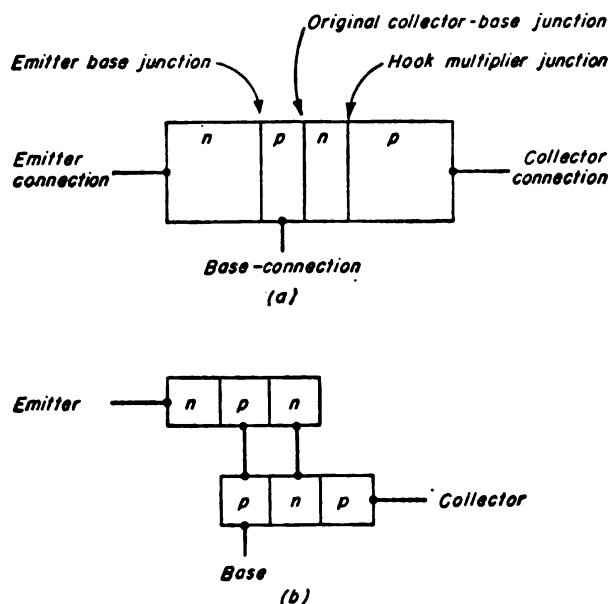


Fig. 6. (a) Schematic form of hook multiplier transistor; (b) equivalent connection of two triode junction transistors to achieve hook transistor characteristics.

region I to III. The difference in time is attributed to what is known as minority carrier storage. When both junctions are forward biased, large currents flow across the two junctions and there is a high concentration of minority carriers in the base region. In region I, on the other hand, the density of these carriers is extremely low because of the reverse bias (see transistors). If after operation in region III for some time, the base-emitter current is suddenly reduced to zero or perhaps reversed, the collector junction cannot experience a sudden change in operation because the density of minority carriers at that location is still high. Consequently, before the collector junction can become reverse biased (as it needs to be in order to enter into region II on the way to region I), it is necessary to wait for the decay of excess carrier density in the base region until the minority carrier density at the collector reaches approximately zero. Until this condition is

reached, the collector current stays practically constant. Once the minority carrier density at the collector junction reaches zero, the junction suddenly offers a high impedance, and the transition to region I through region II commences. The delay time in the process just described is called storage time. It is responsible for slowing up the pulse response of junction transistor circuits and to avoid its effects, semiconductor diodes are often employed in transistor pulse circuits to keep the collector from going into current saturation. Fig. 7 shows a blocking oscillator circuit with two diodes used to limit the operating range of the transistor. Diode A insures that the collector voltage will never reach zero, so that collector current saturation cannot occur. Diode A insures that the collector voltage will never reach zero, so that collector current saturation cannot occur. Diode B prevents the reverse voltage applied between collector and base from becoming large enough

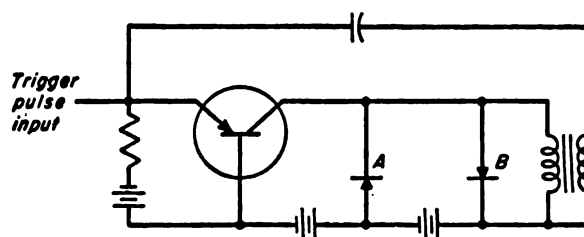


Fig. 7. Blocking oscillator circuit.

to injure the transistor. Diodes may be employed in a corresponding fashion to limit voltage excursions in junction transistor multi-vibrators.

In spite of their limitations, at the present time transistors offer opportunities for far more versatility in low voltage-low current circuit design than do vacuum tubes. Considerable advances in the devices themselves and in their application are expected in the future.

TRANSISTOR, JUNCTION. A solid state device in which the emitter and collector connections are large surface contact (low resistance). The emitter current is slightly larger than the collector current and the base current is very small. (Contrast with **transistor, point contact**.)

TRANSISTOR, POINT CONTACT. A solid state device in which the emitter and collector connections are point contact (high resistance). The collector current is larger than the emitter current. (Contrast with **transistor, junction**.)

TRANSIT TIME. (1) In **electron tubes**, the time for electrons to travel from the cathode to the plate. In high-frequency tubes, the distance from the cathode to the plate is reduced as much as possible in order to produce rapid response. (2) The time required for Mercury or Venus to pass across the face of the sun.

TRANSITION ENGINEERING. The engineering associated with the movement of a project from research and development into detailed design and production.

TRANSLUNAR SPACE. **Space, translunar.**

TRANSMISSIBILITY. The ratio of transmitted force to the applied force in a mechanical system.

TRANSMISSION LINE. The conducting system for electrical energy between two or more points. In communication circuits, certain properties of the line become important. This is due to the much shorter wavelengths used in such circuits so the lines used will frequently be several wavelengths long. Thus at 60 cycles (commercial power frequency) a line would have to be a little over 3000 miles long to be a wavelength while in the middle of the audio range (5000 cycles) it would only

need to be about 37 miles and at the ultra high radio frequencies only a few inches. If a line has a length of the order of a wavelength or more and is not matched reflection and resultant standing waves will result. Often this is a serious drawback to its useful function but for high radio frequencies this property is used to great advantage. A line having standing waves appears at its input terminals to be a resonant circuit (alternately as a series and a parallel type) when adjusted to multiples of a quarter-wave in length. Since at the very high radio frequencies a quarter-wavelength line is only a few inches long, such lines are often used to serve as resonant circuits for **tanks** in **oscillators**, **amplifiers**, etc. Used in this connection they are superior to ordinary lumped inductance and capacitance circuits as they have a much higher **Q** and when properly constructed will cause much lower radiation losses. If these lines are adjusted in length to something other than quarter-wave multiples they act as inductance or capacitance, depending upon the exact length. Such lines are used for a variety of functions, e.g., **tanks**, radio-frequency **chokes**, tuning elements, coupling elements, etc.

TRANSMISSION LINE, COAXIAL (CONCENTRIC). A **transmission line** consisting of two coaxial cylindrical conductors.

TRANSMISSION LINE, SHIELDED. A **transmission line** whose elements essentially confine propagated electrical energy to a finite space inside a conducting sheath.

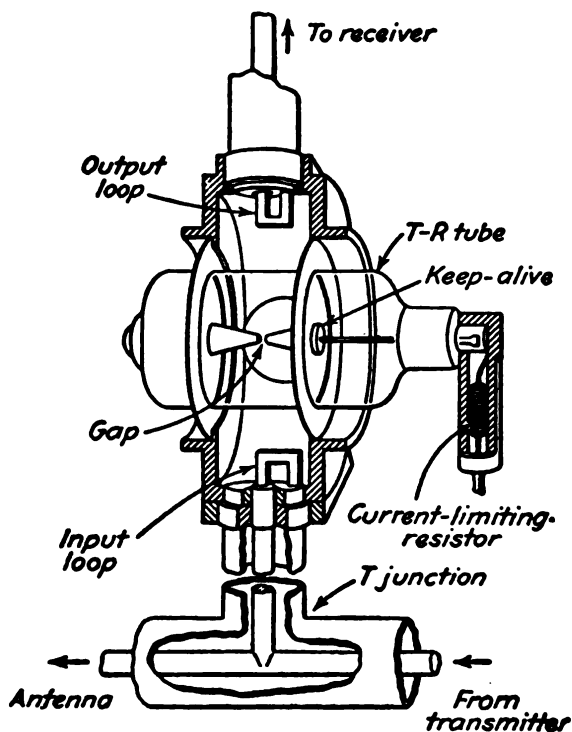
TRANSMISSION LOSS (or Gain). The transmission loss of a system joining a load having a given electrical, mechanical rectilinear, mechanical rotational or acoustical impedance, and a source having a given electrical, mechanical rectilinear, mechanical rotational or acoustical impedance and which impresses a given electromotive force, force, torque or pressure, is expressed by the logarithm of the ratio of the power actually delivered to the load, to the power delivered to the load under some reference condition. For a loss the reference power is greater. For a gain the reference power is smaller.

TRANSMISSION MODE. The various transmission modes in a **waveguide** are characterized by the electric and magnetic field pat-

terns in a plane normal to the guide axis. When the magnetic vector is perpendicular to the direction of travel, the wave is *transverse magnetic*, or a TM-wave. When the electric vector is transverse, it is a *transverse electric*, or TE-wave. If both vectors are perpendicular to the direction of travel, the wave is *transverse electromagnetic*, or a TEM-wave. There are an infinite number of transmission modes in a guide, but each mode possesses a *cut-off frequency*; waves of lower frequency cannot be propagated by the corresponding mode. The lowest of these frequencies is the absolute cut-off frequency of the guide, and the corresponding mode is the dominant transmission mode. Note that a pair of parallel wires is a waveguide possessing a cut-off frequency of zero, i.e., direct current is propagated.

TRANSMISSOMETER. An electronic device used in meteorology to determine atmospheric visibility by measuring the amount of light passing between two points.

TRANSMIT-RECEIVE SWITCH (T-R SWITCH) (T-R GAP) (T-R TUBE). An open spark gap or gas-filled tube used in a duplexer.



Typical T-R box (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc.)

At frequencies above 3000 Mc, the gaps are usually incorporated into cavities because of lower losses. In order to reduce the field strength required for breakdown of the T-R tube, the tube is provided with a keep-alive electrode. A typical assembly for coaxial lines is shown.

TRANSMITTANCE. The ratio of the **radiant power** transmitted by a body to the total radiant power entrant to the body. Commonly, the body is in the form of a parallel-sided plate, and the radiation in the form of a parallel beam incident normally on the surface of the plate. Transmission measurements should be corrected for **reflection** and, in most cases, for **scattering**. Transmittance so corrected is sometimes called **internal transmittance**. If only the emergent radiation which is parallel to the entrant beam is observed, the transmittance is called **specular**. If all the emergent radiation is observed, the transmittance is called **diffuse**. The transmittance may be measured for any radiation, for visible light (optical transmittance), or as a function of the wavelength of the radiation (spectral transmittance).

TRANSMITTER. (1) A device for converting sound waves into corresponding electrical oscillations, e.g., a **microphone** or telephone transmitter. (2) In radio communications, the complete group of equipment utilized in converting sound, or an **audio-frequency** electrical signal into the modulated **radio-frequency** signal fed to the **antenna**. The usage varies somewhat and may connote the modulators and radio-frequency stages, or may be applied to more or less of the equipment constituting the complete broadcasting system.

TRANSMITTER, AMPLITUDE-MODULATED. A transmitter which transmits an amplitude-modulated wave. In most amplitude-modulated transmitters, the carrier frequency is stabilized.

TRANSMITTER, CRYSTAL-CONTROLLED. A transmitter whose carrier frequency is directly controlled by the electro-mechanical characteristics of a piece of material of crystalline structure (a crystal).

TRANSMITTER, CRYSTAL-STABILIZED. A transmitter employing automatic frequency

control, in which the reference frequency is that of a crystal oscillator.

TRANSMITTER, DOUBLE-SIDEBAND. A transmitter which transmits the carrier frequency and both sidebands resulting from the modulation of the carrier by the modulating signal.

TRANSMITTER, FREQUENCY-MODULATED. A radio transmitter which transmits a frequency-modulated wave.

TRANSMITTER, SINGLE-SIDEBAND. A transmitter in which one sideband is transmitted and the other is effectively eliminated.

TRANSMUTATION. The process whereby an atomic nucleus of one species changes into one of a different species, often accomplished by bombardment with nuclear particles, as in a cyclotron or nuclear reactor.

TRANSONIC. Sonic, Tran-.

TRANSONIC FLOW. Flow in which regions of both subsonic and supersonic velocities are present.

TRANSPIRATION COOLING. Cooling; sweat cooling.

TRANS-PLANETARY SPACE. Space, trans-planetary.

TRANSPONDER. Usually a beacon containing a receiver and transmitter. The purpose is to increase the energy level of the target or missile signal in order that the surveillance range can be extended. The transponded signal may be at the same frequency as the surveillance radar or it may be preset at some value which is perhaps 50 megacycles different. Under these conditions the surveillance radar transmits at one frequency and the transponder transmits back at another frequency. Most transponders emit signals only when triggered by the pulses of an interrogating radar set.

TRANSURANIC ELEMENTS. Elements of atomic number 93 or greater, i.e., "beyond" uranium, which is element 92. These are: 93, neptunium, 94, plutonium, 95, americium, 96, curium, 97, berkelium, 98, californium, 99, einsteinium, 100, fermium, 101, mendelevium, and 102, nobelium.

TRANSVERSE ACCELERATION. Acceleration in a direction transverse to the longitudinal axis of a body; specifically: (a) A lateral acceleration of an aircraft, rocket, etc. (b) A back-to-chest, chest-to-back, or side-to-side acceleration of the human body. (See **back-to-chest acceleration**, **chest-to-back acceleration**.)

TRANSVERSE ELECTRIC WAVE. In electronics, an electromagnetic wave in which the electric field vector is perpendicular to the direction of propagation. Abbreviation: *TE*.

TRANSVERSE ELECTROMAGNETIC WAVE. An electromagnetic wave in which both the electric field (*E*) and the magnetic field (*H*) vectors are perpendicular to the direction of propagation. Abbreviation: *TEM*.

TRANSVERSE MAGNETIC WAVE. An electromagnetic wave in which the magnetic field (*H*) vector is perpendicular to the direction of propagation.

TRANSVERSE MERCATOR PROJECTION. The standard military map projection used between 80°N and 80°S because of its minimal distortion. It is produced by projecting to a cylinder placed tangent to a meridian. It is a conformal projection, since angles measured on the projection from grid coordinates closely approximate their true values. Length corrections are the same in all directions, increasing outward from the tangent meridian. (See **Mercator**.)

TRANSVERSE WAVE. A wave in which the direction of displacement at each point in the medium is perpendicular to the direction of propagation. (In other words, waves in which the movement of individual particles is at right angles to the direction of propagation). They are the opposite of longitudinal waves. (See also **wave, transverse electric**, **wave, transverse electromagnetic** and **wave, transverse magnetic**.)

TRAP. (1) An absorption filter used to trap or remove an undesired signal from a receiver, as in the sound trap used in the video amplifier of a television receiver to prevent the sound signal from interfering with the picture. (2) A device designed to reduce the effect of vapor pressure of the mercury or oil in a diffusion pump on the high-vacuum side of the system.

TRAPPED PROPELLANT. In a liquid-propellant rocket engine, the residual propellant in the feed lines which cannot be used because of inadequate suction head. Trapped propellant plus engine dry weight equals engine net weight.

TRAVELING PLANE WAVE. Wave, traveling plane.

TRAVELING-WAVE TUBE. Tube, traveling-wave.

TRICON. A radar system in which the receiver records the coincidence of received pulses from a group of three ground stations pulsed in variable time sequence.

TRIDAC. An electromechanical missile simulator; it is in use at the Royal Aircraft Establishment, England.

TRIDOP. An electronic position-finding system consisting of a master station (having a master receiver, master transmitter and timing transmitter), and three additional receiving stations. In the missile there is a CW transponder which radiates to each of these geographically distributed information receivers. The operation of the system is based upon the **Doppler effect** as noted at each of these ground stations, comparing the missile signal to the master ground station signal.

TRIETHYLALUMINUM (TEA). The compound $(C_2H_5)_3Al$, a component of **high-energy fuels**.

TRIETHYLAMINE. The compound $(C_2H_5)_3N$, a possible component of rocket fuels. It has a boiling point of $192^\circ F$, a freezing point of $-175^\circ F$, and a specific gravity of 0.728.

TRIETHYLBORON (TEB). The compound $(C_2H_5)_3B$, a possible component of **high-energy fuels**.

TRIGGER. To set off or initiate a certain action in an electrical circuit by the application of a pulse of voltage.

TRIGGER CIRCUIT. A multivibrator circuit in which either of the two tubes can operate stably, but the firing of either tube extinguishes the other. The "flip-flop" action is produced by a trigger pulse in the grid of both tubes. Modifications make possible the

use of positive or negative triggering, a double flip-flop or one shot operation. (Used in radar and counting circuits.)

TRIM. In aerodynamics, a steady-state (static) condition wherein the wing of a missile is deflected to provide the necessary lifting or normal force; it is required that the overall moments acting on the full configuration missile must be zero. The missile is said to be trimmed when it is at its equilibrium (total moments equal zero) angle of attack for a given control surface setting.

TRIMETHYLALUMINUM (TMA). The compound $(CH_3)_3Al$, a possible component of rocket fuels.

TRIMETHYLTRITHIOPHOSPHINE. The compound $(CH_3S)_3P$, a possible component of rocket fuels. It has a boiling point of $165^\circ F$, a freezing point of $-70^\circ F$, and a specific gravity of 1.227.

TRIMMER. A corrective device to make small changes in electrical or mechanical quantities.

TRIMMER CAPACITOR. A small capacitor used to adjust a tuned circuit to the desired resonance frequency. Essential in tracking **superheterodyne receivers**.

TRINITROTOLUENE (TNT). An explosive having the chemical formula $C_6H_2CH_3(NO_2)_3$. It is a yellow crystalline material which melts at $177^\circ F$ ($80.8^\circ C$). It has a specific gravity of 1.654. It is slightly more sensitive to shock than ammonium picrate, but is handled with comparative safety. It is the standard high explosive used in shells and bombs and is sometimes considered as a rocket fuel. It is toxic and prolonged exposure may be dangerous.

TRIODE. A three-electrode **electron tube** containing an anode, a cathode, and a control electrode.

TRIPLE POINT. (1) A point on a pressure-temperature diagram at which liquid, solid, and vapor are in equilibrium. (2) In supersonic aerodynamics, the point of intersection of the **incident front**, the **reflected front**, and the **Mach front**.

TRITIUM. The radioactive isotope of hydrogen having an atomic number 3 (H^3). It

emits beta rays and has a half life of 12.5 years.

TRITON. (1) The nucleus of the tritium atom. (2) A U.S. Navy surface-to-surface missile carried to the preliminary design stage by the Applied Physics Laboratory of Johns Hopkins University as part of the **Bumblebee Project**, which also yielded the **Talos** and **Terrier** missiles, which was cancelled in 1952. The prime manufacturing contract was given to McDonnell Aircraft Corporation, with the guidance work being done by Kearfott Gyroscopic Company. (See **missile, guided**.)

TRIZON. A three-ton Razon.

TROPOPAUSE. The boundary or zone of transition between the **troposphere** and the **stratosphere**. It varies in height from about 55,000 feet at the equator to 25,000 feet over the poles. The height also changes with the seasons and with the passage of cyclones and anticyclones. The temperature at the tropopause ranges from approximately -67°F above the poles to about -100°F over the equator. (See **atmosphere**, and diagram in that entry.)

TROPOSPHERE. The region of the atmosphere extending from the surface of the earth up to the tropopause (approximately 5-10 miles); characterized by convective air movements and a pronounced vertical temperature gradient decreasing with altitude, in contrast to the convectionless and almost vertically isothermal stratosphere above the tropopause. It contains about 75% of the total weight of the atmosphere.

TROPOSPHERIC WAVE. A radio wave that is propagated by reflection from a place of abrupt change in the dielectric constant or its gradient in the troposphere. In some cases the ground wave may be so altered that new components appear to arise from reflections in regions of rapidly changing dielectric constants; when these components are distinguishable from the other components, they are called tropospheric waves.

TRUE AIRSPEED. Airspeed, true.

TRUE ALTITUDE. Altitude above mean sea level. (Cf. **absolute altitude**.)

TRUE HEADING. Heading, true.

T-TIME. The exact time of launching a missile or test vehicle. By convention it is the time of first motion or takeoff. From it all flight times are measured. All time before launch is designated as X-time (i.e., the "unknown" time). T-time and X-time are sometimes used interchangeably. In these cases the distinction of before flight and after takeoff is made by the use of a minus or plus sign. For example, X-120 would be read: X minus 120, meaning 2 hours before launch time. It is of advantage to distinguish between X and T times, since most ballistic missiles do not takeoff immediately when "zero time" is reached, because the motor often requires from 15 seconds to nearly a full minute to develop the full thrust necessary to lift off the missile.

TTAF. Technical Training Air Force; Gulfport, Mississippi.

TTE. Tentative Table of Equipment.

TUBE, ACORN. A tube (see **tube, electron**) having small electrodes of essentially conventional shape which has an upper frequency limit of approximately 1200 mc. Its name comes from the fact that its shape and size is approximately that of an acorn.

TUBE, CAMERA (PICKUP TUBE). An electron-beam tube (see **tube, electron-beam**) in which an electron-current or charge-density image is formed from an optical image and is scanned in a predetermined sequence to provide an electrical signal.

TUBE, CATHODE-RAY. An electron-beam tube (see **tube, electron-beam**) in which the beam can be focused to a small cross-section on a surface, and varied in position and intensity to produce a visible pattern. (For more detailed discussion, see **cathode ray tube**.)

TUBE, DIODE. An electron-tube diode. (See **tube, electron**; also **diode**.)

TUBE, ELECTRON. An electron device in which conduction by electrons takes place through a vacuum or gaseous medium within a gas-tight envelope. The electron tube is a device in which **electrons** are freed from the restraints of a solid conductor, pass across a free space (vacuum or gas at low pressure) and are again collected by a solid conductor,

but during this passage in free space are controlled in manners which would be impossible if they had not been temporarily freed. (See also **electron tube circuits**.)

TUBE, ELECTRON-BEAM. An electron tube, the performance of which depends upon the formation and control of one or more **electron-beams**.

TUBE, HOT-CATHODE. An electron tube (see **tube, electron**) containing a hot cathode.

TUBE, LOCAL OSCILLATOR. An electron tube in a heterodyne conversion transducer to provide the local heterodyning frequency for a mixer tube. (See **tube, mixer**.)

TUBE, MIXER. An electron tube (see **tube, electron**) that performs only the frequency-conversion function of a heterodyne conversion transducer when it is supplied with voltage or power from an external **oscillator**.

TUBE, PHOTOELECTRIC. Phototube.

TUBE, SOFT. (1) A tube which has not been completely evacuated, or a vacuum tube which has lost part of its vacuum due to gas released from the electrodes and envelope. (2) A tube which has been evacuated and recharged with an inert gas.

TUBE, THERMIONIC. An electron tube (see **tube, electron**) in which one of the electrodes is heated for the purpose of causing electron or ion emission from that electrode.

TUBE, THYRATRON. Thyatron.

TUBE, TRAVELING-WAVE. A broad-band, microwave tube which depends for its

characteristics upon the interaction between the field of a wave propagated along a **waveguide** and a beam of electrons traveling with the wave. In this tube, the electrons in the beam travel with velocities slightly greater than that of the wave, and on the average are slowed down by the field of the wave. The loss in kinetic energy of the electrons appears as increased energy conveyed by the field of the wave. The traveling-wave tube may, therefore, be used as an **amplifier** or as an **oscillator**. In addition to the type of tube shown here the magnetron may function as a traveling wave tube.

TUBE, TRIODE. Triode.

TUBULAR GRAIN. A solid propellant grain cast in the form of a tube which burns with a constant value of K_n . The thickness of the propellant grain, termed the web thickness, determines duration of the burning.

TUMBLING. (1) The end-over-end motion of a missile that has lost its longitudinal stability. (2) A condition which occurs when two of the three frames of a **gyroscope** become co-planar. Under these circumstances, the gyro wheel rotates about a diameter as well as about its polar axis, resulting in a loss of reference.

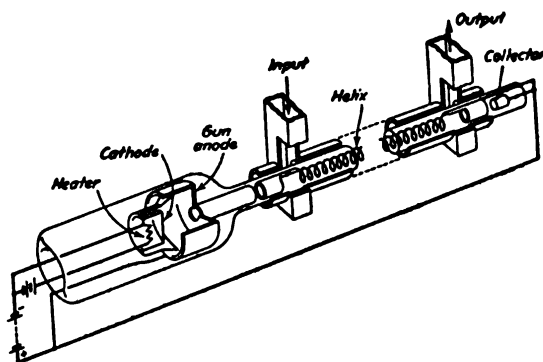
TUNER, SLUG. Slug tuning.

TUNER, WAVEGUIDE. Waveguide tuner.

TUNGAR RECTIFIER. A rectifier using a tungar bulb, made or licensed by the General Electric Company. A tungar bulb is a gas-filled tube containing two tungsten electrodes. It is often used in battery chargers or for supplying d-c for other purposes. The name is derived from *tungsten-argon* (argon being the gas used to fill the tube).

TUNGSTEN. Metallic element. Symbol W. Atomic number 74. Tungsten is also called wolfram, its German name.

TUNING. In electronics, the adjustment of circuit components to achieve resonant conditions. It consists of changing capacitance, inductance or other variables (including the physical size of resonant cavities by insertion of plugs or slugs) to obtain the most efficient operation.



Schematic diagram of the traveling-wave amplifier (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc.)

TUNING SCREW. A screw inserted into the top or bottom of a **waveguide** (parallel to the E-field) to develop **susceptance**, the magnitude and sign of which is controlled by the depth of penetration of the screw. One screw, variable in position along the guide, or two or three fixed-position screws, are required in most matching or tuning situations.

TURBINE. A rotating machine operated by the force of a fluid impinging on curved or angled vanes mounted circumferentially on a shaft. Its operation is the same as that of the water wheel. In missile applications, high speed turbines (15,000-20,000 rpm) are sometimes used for the purpose of driving fuel pumps. The balance of these turbines must be nearly perfect to avoid disastrous stresses at such speeds. The fluids used to drive turbines are liquids, gases, or vapors. Turbines may themselves drive centrifugal or axial flow pumps, compressors, blowers or fans.

TURBOJET (TURBOJET ENGINE). A thermal **jet engine** whose air is supplied by a turbine-driven compressor; the turbine being activated by exhaust gases from the combustion chamber.

TURBOPROP (PROPELLER-TURBINE ENGINE; PROP-JET). A gas-turbine engine designed to drive a propeller for use at intermediate aircraft speeds.

TURBOPUMP. A turbine-driven pump.

TURBORAM JET. A name applied to a turbojet with an afterburner attached.

TURBOROCKET. A **thermojet** engine in which a rocket supplies high pressure gas to drive a compressor which, in turn, supplies air which further combusts with the rocket gases. The final products of combustion form a propulsive jet stream.

TURBULENT FLOW. In aerodynamics, a condition wherein the air close to the surface is of a turbulent nature; that is, contains unpredictable eddies and generally *rough* flow. The opposite of **laminar flow**.

TURPENTINE. A possible rocket fuel. Its chemical formula is $C_{10}H_{16}$. Its boiling point is between 313-349°F, freezing point -112°F and its specific gravity is 0.845.

TV-0, TV-1, TV-2, TV-3BU, etc. The designations for test vehicles in the **Vanguard** series. TV is an abbreviation for test vehicle, while BU means back-up.

TWEETER. A high frequency loudspeaker. It is used in combination with a low frequency loudspeaker (a "woofer"), for extended high fidelity response.

TWILIGHT. The half-light period of time before sunrise or sunset, but before dark. There are four overlapping twilights: civil, observational, nautical, and astronomical. *Civil twilight* exists when the sun is between horizon and a point 6° below the horizon (measured at the middle of the sun). *Observational twilight* begins when the sun is about 10° below the horizon. The horizon can be seen and navigational stars are visible. *Nautical twilight* exists when the sun is between the horizon and a point about 12° below the horizon. On clear nights the use of a sextant is possible throughout nautical twilight. *Astronomical twilight* exists when the sun is between the horizon and about 18° below the horizon. The stars are fully visible.

TWISTED PAIR. A cable composed of two insulated conductors twisted together either with or without a common covering.

TWO-BODY PROBLEM. The so-called two-body problem is the foundation of **celestial mechanics**. The solution of the problem requires two fundamental assumptions: (1) that two and only two objects exist in the universe, and (2) that some law of force between the two objects is given. With these assumptions admitted, the two-body problem may briefly be stated as follows: given the relative positions of two objects at any instant, together with their motions and masses at that instant, to predict the positions and motions of the objects at any subsequent instant. The use of solutions to the two-body problem is a mathematical convenience to arrive at actual motions and positions by computing the effects of the other bodies (that affect the two-body system significantly) as **perturbations**.

TWO-DIMENSIONAL FLOW. In aerodynamics, a flow in which two Cartesian coordinates are sufficient to specify conditions. The fluid undergoes a significant change of direc-

tion in one plane only, i.e., at right angles to the direction of the flow, as in the case of flow over a wing of infinite span. Wind tunnel tests are facilitated by two-dimensional observations, assuming uniform conditions along any line perpendicular to the walls of the tunnel.

TWO-STAGE CENTRIFUGAL COMPRESSOR. Normally a compressor of the centrifugal type in which the compressed air from the low-pressure or first stage, is passed into the second stage and recompressed. This affords higher compression ratios than the theoretical maximum of approximately 4:1 available from a single-stage centrifugal compressor.

TWO-STAGE MISSILE. (1) Any missile

consisting of two stages or phases of powered flight using two distinct power plants. (2) A missile consisting of a booster stage and a second or sustainer stage. At staging the booster or first stage (consisting of propulsion system, tankage, structure and autopilot) is discarded. The second stage engine may be required to start at altitude or it may be ground started giving thrust during the boost phase. (See **tandem missile**.)

TYPE TEST. A test made on a typical or sample article to demonstrate that the particular design is adequate for its intended use. A type test is usually "one of a kind" and the test input may be to design extremes: (e.g., structural test to failure.

U

U. (1) Unit (u). (2) Overall coefficient of heat transfer (U). (3) Density of radiant energy (u). (4) Total internal energy (U), internal energy per atom or molecule (u or u_m), internal energy per unit mass (u), internal energy per mole (U_M , U , or u). (5) Potential energy (U). (6) Radiant energy (U), spectral radiant energy (U_λ), radiant energy density (u). (7) Reaction velocity (u). (8) Velocity (u), velocity, linear or particle (u), velocity at time t (u or u_t), velocity, average (u_{av} or \bar{u}), velocity, group (u_g or u), velocity components (u_x , u_y , u_z), velocity initial (u_0), velocity, phase or wave (u_w or u_ϕ). (9) Time-independent wave function (u). (10) Uranium (U).

UAL. Unit Authorization List. An allowance list of equipment for each operational unit.

UAM. Underwater-to-air missile.

U-DETA. Hydryne.

UDMH. Unsymmetrical dimethyl hydrazine.

UEE. Unit essential equipment.

UHF. Ultra high frequency. (See frequency spectrum.)

ULLAGE. The volume of a propellant tank in excess of the propellant. It is provided to allow for thermal expansion of the propellant and for accumulation of gaseous products evolved from the propellant.

ULTIMATE LOAD. Load, ultimate.

ULTIMATE OPERATIONAL CAPABILITY (UOC). That phase of a weapon system's use which follows IOC (Initial Operating Capability) and which utilizes unit equipment.

ULTRA HIGH FREQUENCY (UHF). A frequency in the band 300-3000 megacycles per second. These frequencies are used for communications over short distances because

of their adaptability to multi-transmissions and their freedom from interferences.

ULTRA SHORT WAVES. Electromagnetic waves of 10-0.1 meters wavelength, i.e., frequencies of 30-3000 megacycles per second. This band includes both the VHF and UHF regions.

ULTRASONIC. A modifier indicating a device or system intended to operate at ultrasonic frequencies.

ULTRASONIC DELAY LINE (ULTRASONIC STORAGE CELL). A contained medium (usually a liquid, e.g., mercury) in which use is made of the propagation time of sound to obtain a time delay of an ultrasonic signal.

ULTRASONIC FREQUENCY. A frequency lying above the audio frequency range. The term is commonly applied to elastic waves propagated in gases, liquids, or solids.

ULTRASONICS. That region of sound frequencies beyond (i.e., of higher frequency than) the audible sound waves.

ULTRAVIOLET RADIATION. A frequency of light higher than the visible light spectrum extending into the region of low frequency x-rays. This spectral region has been observed over more than three "octaves" of the radiation frequency scale, roughly from 4000 Å (angströms) at the extremity of the violet to below 140 Å on the border of the x-ray region. The ultra-violet range has pronounced photographic and ionizing effects, and so is easily detected. The chief hindrance to its study is its rapid absorption in most forms of matter; even air is a serious obstacle to the shorter ultra-violet waves. The sun is an intensely hot source of radiation, but its observable spectrum ceases quite abruptly just below 3000 Å because, it is believed, of absorption by atmospheric gases, chiefly oxygen and ozone. (This is fortunate, as the shorter radiations may be very injurious to living tissues.)

UMBILICAL CORD. A cable fitted with a quick disconnect plug on the missile, through which missile equipment is controlled and tested while the missile is still attached to launching equipment or parent plane.

UME. Unit mission equipment.

UNCAGING. Electrical disconnection of the erection circuitry in a displacement **gyroscope** system. Normally gyroscopes are caged when they are first erected, to insure alignment of the gyro's sensitive axes with the missile axes at the time of launching. Sometimes the gyros are not uncaged until after the **boost** phase of launching.

UNDER-EXPANSION. In rocket motor design, an unavoidable condition where the exhaust nozzle is not allowed to expand the combustion gases to the pressure of the surrounding space. This is necessary because the optimum expansion ratio of any motor is dependent upon the altitude for which it was designed. A motor designed for operation at sea level will be far under-expanded for space travel. Under-expansion causes a loss of **thrust**.

UNDERGROUND BURST. A nuclear explosion with its center of detonation beneath the surface of the ground.

UNDERGROUND LAUNCHER. A launching complex capable of **launching** a missile from underground. Contrast with underground **storage**.

UNDERWATER BURST. A nuclear explosion with its center of detonation beneath the surface of the water.

UNDERWATER-TO-AIR MISSILE (UAM). Missile, ground-to-air; model designation.

UNDULATION OF THE GEOID. A harmonic variation in the rotation of the earth which causes **gyroscopes** to have an 84-minute oscillation. The error resulting from this oscillation is regular and predictable. It is dependent upon the radius of the earth, and is equivalent to the period of a pendulum equal in length to the radius of the earth. (See also **accelerometer errors**.)

UNHEALTHY. A test range term designating a missile or test vehicle which does not perform as expected. It is not necessarily **erratic**.

UNIT(S) AND DIMENSION(S). Every physical measurement involves the comparison of two quantities of the same nature, e.g., two lengths, two electrical currents, etc. The same results will be achieved by two different observers only if they have agreed to use the same standard as one of these quantities. To provide such standards, certain fundamental units have been established by custom, by national legislation, and by international agreement. The definitions of these fundamental units throughout this volume are consistent with the legal definitions or with accepted custom in the United States and in Great Britain. In a few cases, such as that of the inch, the two countries have definitions which do not agree precisely; in these instances both definitions are given.

The specification of a physical quantity must tell both what standards were used in the measurement and how the quantity compares with these standards. The quantity is therefore expressed as the product of a pure number, giving the latter piece of information, and a unit which gives the former. Two equal quantities may be represented by quite different numbers if they are measured in different units. Thus:

$$1 \text{ mile} = 5280 \text{ feet} = 1609 \text{ meters.}$$

All quantities which can be expressed in the same units are said to have the same physical dimensions. Thus two square miles and ten acres, while they are not equal, have the same dimensions, those of area, or of length squared.

The great majority of physical quantities can be measured in terms of derived units, which are defined in terms of the fundamental units. Thus *velocity* is defined as the time rate of change of position and is determined by a measurement of the change of position, i.e., a length, l , during a time interval, t . The average velocity during this interval is $v = l/t$. The unit of velocity is therefore a unit of length divided by a unit of time, such as feet/second, miles/hour, meters/minute, etc. When quantities measured in terms of derived units are given in this Dictionary, their dimensions in terms of fundamental units are usually specified. To avoid the complexity that would result if every quantity were expressed directly in terms of fundamental units, the dimensions are often expressed in terms of derived units intermediate between those of the defined quantity and the primary stand-

ards. Thus the **Planck constant**, h , is given dimensions of erg seconds. The erg itself has the dimensions of force times distance, and force has the dimensions of a mass times a length divided by the square of a time. Hence, letting m , l , and t represent mass, length, and time, respectively, the dimensions of the Planck constant are

$$[h] = [(ml/t^2) \cdot (l)(t)] = [ml^2/t],$$

so that it may be expressed in units of the gram centimeter squared per second.

Which physical quantities should be chosen as fundamental, or even how many should be chosen, are matters of choice and convenience. This is true because most physical laws express proportionalities, rather than equalities. As an example, consider the usual statement of the **Newton second law of motion**, that the acceleration, a , produced in a body of mass m by a force, f , is directly proportional to the force and inversely proportional to the mass. This law may be written as

$$a \propto f/m.$$

It is usually convenient to change this proportionality to an equation by the insertion of a constant of proportionality, K :

$$Ka = f/m.$$

This equation involves three physical quantities, a , f , and m . If all three of these are defined arbitrarily, either as fundamental units or in terms of derived units, the dimensions of K will be determined by the equation. On the other hand, any two of the physical quantities may be defined arbitrarily, and a further arbitrary choice may be made as to the dimensions and magnitude of K . The equation may then be used as a defining equation of the third quantity. Whether one or the other choice is convenient depends on the problem to which Newton's second law is being applied. The consequences of the various possible choices in this case are discussed below, in the section on Mechanical Units.

Each time that an arbitrary choice such as that just discussed is made, a new system of units is established. Each of these systems is self-consistent but the various systems are not necessarily consistent with each other. Whenever a choice exists as to the system of units in which a quantity may be defined, this Dictionary has either given two or more definitions, specifying the system in which

each is appropriate, or has stated the dimensions of the quantity in such a way that the definition may be modified when a different system is employed. The inclusion of all of the hundred or more systems that have been used would have resulted in confusion, hence only a limited number of systems are accepted here. These systems are listed in the next few pages, and the relations among them are outlined.

Nearly all physical measurements can be reduced to the measurement of mechanical, thermal, or electromagnetic quantities, or to some combination of these. The systems of units which are used for each are treated below.

MECHANICAL UNITS

All mechanical measurements involve the motion of material bodies, described in terms of space and time coordinates. Hence length and time are almost universally chosen as fundamental quantities. The present standard of time is the *mean solar day*, defined as the average period between two successive transits of the sun across the meridian at any given spot on the earth's surface. The most commonly used unit of time is the *second*, defined as 1/86,400 part of a mean solar day.* Two independent length standards, the *meter* (M) and the *yard* (yd), are in common use. From the former is derived the *centimeter* (1 cm = 1 M/100) and from the latter, the *foot* * (1 ft = 1 yd/3).

*This is not a completely satisfactory definition, because tidal action is gradually slowing the rotation of the earth. It therefore seems probable that the second will be redefined in the near future, as a specified multiple of a period of vibration of some particular molecule, probably ammonia.

*Two slightly different definitions of the foot are in use in the United States. They disagree with each other and with the definition used in Great Britain by a few parts in a million. The British foot is defined as exactly one-third of an Imperial yard; the National Bureau of Standards and the U.S. Coast and Geodetic Survey define the foot as exactly 1200/3937 meter; the American Standards Association, B48.1, 1933 and 1947, defines the foot as exactly 0.3048 meter. The differences are significant only in refined measurements, the relative lengths of the three feet defined above being

$$0.914399:0.914402:0.914400.$$

It seems possible that both the meter and the yard may be redefined within a few years in terms of the wavelength of a particular spectral line, instead of as material standards.

In physics, chemistry, and electrical engineering, as well as in much of mechanical engineering, the commonly employed systems of mechanical units use length, mass, and time as fundamental quantities. These are known as *length-mass-time* systems. Three such systems, the *meter-kilogram-second* (MKS), the *centimeter-gram-second* (cgs), and the *foot-pound-second* (f lbm s) systems, are very widely used. In all three systems the constant of proportionality in Newton's law is chosen as a dimensionless quantity of unit magnitude.

In structural engineering and in some mechanical engineering applications, forces play a more important part than do masses. Systems which use length, force, and time as fundamental units are therefore convenient. The length-force-time system to be discussed here is the *foot-pound-second* system. The unit of force, the *pound (force)*, is defined as the weight of a pound mass at a point on the earth's surface at a point where the acceleration due to gravity is 32.174 ft/sec². In this system the unit of mass, the *slug*, is a derived unit, equal to 1/32.174 lbm. In order that confusion may not be caused by the use of the pound both as a unit of mass and as a unit of force, the pound (mass) is often abbreviated as lbm, the pound (force) as lbf.

A third type of system defines both the mass and force as well as units of length and time. In such *mass-force-length-time* systems, the constant of proportionality in New-

ton's second law takes on dimensions and a non-unitary value. Two such systems, the lbm-lbf-ft-sec and the gm-gf-cm-sec system are employed here. The abbreviation gf is used to indicate a *gram (force)*, the unit of force, which is defined as the weight of a one-gram mass under the action of a gravitational acceleration of 980.665 cm/sec².

The more important units in each of the six systems and the relations among these units are shown in Table 1. As an example of the use of this and similar tables, suppose that a moment of inertia is specified as 1050 gm cm², and that it is desired to express this quantity in the f lbm s system. The use of conversion factors from the table shows that

$$1050 \text{ gm cm}^2 \times \frac{2.205 \text{ lbm}}{1000 \text{ gm}} \times \frac{(3.281 \text{ ft})^2}{\text{M}^2} \\ \times \frac{\text{M}^2}{(100 \text{ cm})^2} = 0.002492 \text{ lbm ft}^2.$$

ACOUSTICAL UNITS

In acoustics, the centimeter-gram-second (cgs) system of units has been and is at present predominantly used; but some practical units such as English and metric system units of length are also being used; and the watt is commonly being employed for designating acoustic power. In recent years there has been a trend toward adoption of the rationalized meter-kilogram-second system of units in many fields of science and engineering.

TABLE 1. RELATIONS AMONG THE SYSTEMS OF MECHANICAL UNITS

QUANTITY	MKS SYSTEM	EQUIVALENTS IN OTHER SYSTEMS				
		cgs System	f lbm s System	f lbf s System	f lbm lbf s System	cm gm gf s System
Length	1 Meter	10 ² cm	3.281 ft	3.281 ft	3.281 ft	10 ² cm
Mass	1 Kilogram	10 ³ gm	2.205 lbm	70.94 slug	2.205 lbm	10 ³ gm
Density	1 K/M ³	10/ ³ gm/cm ³	62.43(10) ⁻³ lbm/ft ³	2.009 slug/ft ³	62.43(10) ⁻³ lbm/ft ³	10/ ⁻³ gm/cm ³
Force	1 Newton	10 ⁵ dyne	7.015 poundal	0.2180 lbf	0.2180 lbf	102.0 gf
Work (Energy)	1 Joule	10 ⁷ erg	23.02 ft poundal	0.7153 ft lbf	0.7153 ft lbf	1.020(10) ⁴ gf cm
Power	1 Watt	10 ⁷ erg/sec	23.02 ft poundal/sec	1.301(10) ⁻³ horse power	0.7153 ft lbf/sec	1.020(10) ⁴ gf cm/sec

TABLE 2. CONVERSION OF PRESENT ACOUSTICAL UNITS INTO MKS UNITS

QUANTITY	DIMENSION	PRESENT UNIT	MKS UNIT	CONVERSION FACTOR*
Sound velocity (particle velocity)	LT^{-1}	cm per second	meter per second	10^{-2}
Volume velocity	L^3T^{-1}	cubic cm per second	cubic meter per second	10^{-6}
Sound energy	ML^2T^{-2}	erg	joule	10^{-7}
Force	MLT^{-2}	dyne	newton	10^{-5}
Sound pressure (sound-energy density)	$ML^{-1}T^{-2}$	microbar	newton per square meter	10^{-1}
Sound-energy flux (sound power of source)	ML^2T^{-3}	erg per second	watt	10^{-7}
Sound intensity (specific sound-energy flux)	MT^{-3}	erg per second per square cm watt per square cm	watt per square meter	10^{-3} 10^4
Acoustic impedance (resistance, reactance)	$ML^{-1}T^{-1}$	acoustical ohm	Mks acoustical ohm†	10^5
Specific acoustic impedance	$ML^{-2}T^{-1}$	acoustical ohm \times square cm	Mks acoustical ohm† \times square meter	10
Mechanical impedance (resistance, reactance)	MT^{-1}	mechanical ohm	Mks mechanical ohm†	10^{-3}

* Multiply the magnitude expressed in present units by the tabulated conversion factor to obtain magnitude in Mks units.

† Mks acoustical ohm and Mks mechanical ohm are proposed terms.

Therefore the Mks units are included in the accompanying Table 2, even though they have not been employed in acoustics.

THERMAL UNITS

Thermal measurements involve, in addition to the mechanical quantities outlined above, the specification of temperature. Two temperature scales are in common use, both being defined in terms of measurements made with a mercury-in-glass thermometer and both having the freezing and boiling points of pure water at normal atmospheric pressure as fixed points. The *Celsius*, or *Centigrade*, scale is obtained if the freezing point is taken as zero degrees and the boiling point as 100 degrees.†

† The definition given is that in common use at present. It is in close agreement with the recommendation of the International Union of Pure and Applied Physics in 1955 that the triple point of water (i.e., the temperature at which ice, water, and water vapor can exist in equilibrium) be defined as 273.16°K and be used as the basis of determining the size of one degree Kelvin. This recommendation would make the Kelvin scale fundamental, rather than the Centigrade scale.

The Fahrenheit scale is obtained if these points are taken as 32 degrees and 212 degrees, respectively. Thus the *degree Centigrade* (°C) is the temperature difference which causes the mercury in a thermometer to expand by 0.01 as much as it expands between the freezing and boiling points. The *degree Fahrenheit* (°F) is defined similarly, and is therefore 5°C/9.

The original definitions of the Centigrade and Fahrenheit scales would limit the measurement of temperature to the range in which the mercury-in-glass thermometer can be used. These scales are extended upward and downward with the help of the gas thermometer and of well established thermodynamic laws. The *Kelvin*, or *absolute*, temperature scale is based on the second law of thermodynamics, and is independent of the properties of any particular substance, except for the definition of the size of a degree. Its zero is the lower limit of temperature, which can be approached but never reached, and the size of a *degree Kelvin* (°K) is taken in such a way that the difference of the temperatures of the freezing

TABLE 3. RELATIONS AMONG THERMAL UNITS

QUANTITY	MKS °C SYSTEM	EQUIVALENTS IN OTHER SYSTEMS			
		MKS °K System	cgs °K System	f lbm s °F System	f lbm s °R System
Temperature difference	1 °C	1 °K	1 °K	1.80 °F	1.80 °R
Temperature	x °C	$(273.16 + x)$ °K	$(273.16 + x)$ °K	$(32 + 9x/5)$ °F	$(491.7 + 9x/5)$ °F
Energy	1 joule = 0.2390 cal	1 joule	$(10)^7$ erg	$9.478(10)^{-4}$ BTU 0.7153 ft lbf	$9.478(10)^{-4}$ BTU

and boiling points of water shall be 100°K. Careful measurements have demonstrated that the zero of the Centigrade scale is at 273.16°K. The *Rankine* temperature scale is an absolute scale in which the degree (°R) is matched to the Fahrenheit thermometer.

Since heat is a form of energy, any of the mechanical units of energy, such as the erg, joule, or foot pound, may be used to measure quantity of heat. Other units, based on the thermal properties of water, had become well established before the first law of thermodynamics was enunciated. The use of these units persists, and several of them are used interchangeably with the mechanical units in this Dictionary. The most widely accepted is the *calorie* (cal) which was originally defined as the heat necessary to raise the temperature of one gram of water through a temperature increase of one degree Centigrade. This definition makes the unit depend on the initial temperature of the water, so the calorie has been redefined as equal to 4.1840 joules. The *kilocalorie* or *large calorie* (kcal) is exactly 1000 cal. The *British thermal unit* (BTU) is the heat required to raise the temperature of one pound of water through one degree Fahrenheit.

The four basic systems of thermal units employed in this volume are summarized in Table 3. Relations among derived units, such as those of specific heat, entropy, etc., may be obtained by methods identical with that outlined in connection with Table 1. For example:

$$\frac{0.0235 \text{ BTU}}{^\circ\text{F}} = \frac{0.0235 \text{ BTU}}{^\circ\text{F}} \times \frac{1 \text{ joule}}{9.478(10)^{-4} \text{ BTU}} \times \frac{1.80^\circ \text{ F}}{1^\circ \text{ K}} = \frac{44.6 \text{ joule}}{^\circ \text{ K}}$$

ELECTROMAGNETIC UNITS

At least eight or ten different systems of electrical and magnetic units are in common use. Each of these is based on a particular choice of a constant of proportionality in an experimentally verified physical law. Some systems start with Coulomb's law, which states that the force, f , between two electrical charges, q_1 and q_2 , separated by a distance r in empty space is directly proportional to the product of the charges and inversely proportional to the square of the distance between them, i.e.:

$$f = K_e q_1 q_2 / r^2,$$

where K_e is a constant that may be chosen for convenience. Such systems are known as electrostatic systems. The choice of K_e as unity and dimensionless, together with the use of the dyne and the centimeter as units of force and length, leads to the *cgs electrostatic system* in which the unit of charge, the *statcoulomb*, is the charge which repels an exactly similar charge, separated from it by one centimeter *in vacuo*, with a force of one dyne. This system is frequently called the *esu system*. Another choice, which is sometimes convenient, takes K_e as a dimensionless constant equal to 4π . This leads to the *rationalized cgs electrostatic system*. In either of the two systems, charge has the dimensions of $\text{dyne}^{1/2} \text{cm}$, equivalent to $\text{cm gm}^{1/2} \text{sec}^{-1}$. All other electrical quantities also have identical dimensions in the two systems, although the sizes of their units differ.

In distinction to the electrostatic systems are the *electromagnetic systems* (emu systems), which start with the law of attraction between currents. If two currents of magnitudes I_1 and I_2 flow in long parallel wires, separated by a distance d *in vacuo*, they attract

TABLE 4. RELATIONS AMONG THE SYSTEMS OF ELECTRICAL AND MAGNETIC UNITS
(The dimensions of the various quantities are shown in square brackets)

QUANTITY	MKS (ABSOLUTE) SYSTEM	EQUIVALENTS IN OTHER SYSTEMS			
		Old International System	cgs esu System	cgs emu System	Gaussian System
Permittivity of empty space (ϵ_0)	$8.855(10)^{-12}$ Farad/M [m ⁻² k ⁻¹ s ⁴ a ²]	$8.859(10)^{-12}$ Int. Farad/M	1 [Dimensionless]	$1.1126(10)^{-12}$ [cm ⁻² s ²]	1 [Dimensionless]
Permeability of empty space μ_0	$1.2566(10)^{-6}$ Henry/M [mks ⁻² a ⁻²]	$1.2560(10)^{-6}$ Int. Henry/M	$1.1126(10)^{-12}$ [cm ⁻² s ²]	1 [Dimensionless]	1 [Dimensionless]
Charge (Q)	1 Coulomb [sa]	1.000165 Int. Coulomb	$2.998(10)^9$ Statcoulomb [cm ^{3/2} gm ^{1/2} s ⁻¹]	0.1 Abcoulomb [cm ^{1/2} gm ^{1/2}]	$2.998(10)^9$ Statcoulomb [cm ^{3/2} gm ^{1/2} s ⁻¹]
Potential difference (V)	1 Volt [m ² ks ⁻² a ⁻¹]	0.999670 Int. Volt	$3.336(10)^{-2}$ Statvolt [cm ^{1/2} gm ^{1/2} s ⁻¹]	(10) ⁹ Abvolt [cm ^{3/2} gm ^{1/2} s ⁻²]	$3.336(10)^{-2}$ Statvolt [cm ^{1/2} gm ^{1/2} s ⁻¹]
Current (I)	1 Ampere [a]	1.000165 Int. Ampere	$2.998(10)^9$ Statampere [cm ^{3/2} gm ^{1/2} s ⁻¹]	0.1 Abampere [cm ^{1/2} gm ^{1/2} s ⁻¹]	$2.998(10)^9$ Statampere [cm ^{3/2} gm ^{1/2} s ⁻¹]
Resistance (R)	1 Ohm [m ² ks ⁻² a ⁻²]	0.999505 Int. Ohm	$1.1126(10)^{-12}$ Statohm [cm ⁻¹ s]	(10) ⁹ Abohm [cms ⁻¹]	$1.1126(10)^{-12}$ Statohm [cm ⁻¹ s]
Electric displacement (D)	1 Coulomb/M ² [m ⁻² sa]	1.000165 Int. Coulomb/M ²	$2.998(10)^9$ Statcoulomb/cm ² [cm ^{-1/2} gm ^{1/2} s ⁻¹]	(10) ⁻⁹ Abcoulomb/cm ² [cm ^{-3/2} gm ^{1/2} s ⁻¹]	$2.998(10)^9$ Statcoulomb/cm ² [cm ^{-1/2} gm ^{1/2} s ⁻¹]
Capacitance (C)	1 Farad [m ⁻² k ⁻¹ s ⁴ a ²]	1.000495 Int. Farad	$8.988(10)^{11}$ cm [cm]	(10) ⁻⁹ Abfarad [cm ⁻¹ s ²]	$8.988(10)^{11}$ cm [cm]
Magnetic dipole moment	1 Ampere M ² [m ³ a]	1.000165 Int. Ampere M ²	$3.336(10)^{-6}$ Statmaxwell/cm [cm ^{-1/2} gm ^{1/2}]	(10) ⁹ Maxwell/cm [cm ^{1/2} gm ^{1/2} s ⁻¹]	(10) ⁹ Maxwell/cm [cm ^{1/2} gm ^{1/2} s ⁻¹]
Magnetic field strength (H)	1 Ampere turn/M [m ⁻¹ a]	1.000165 Int. Ampere turn/M	$3.767(10)^8$ Statoersted [cm ^{1/2} gm ^{1/2} s ⁻¹]	$1.257(10)^{-2}$ Oersted [cm ^{-1/2} gm ^{1/2} s ⁻¹]	$1.257(10)^{-2}$ Oersted [cm ^{-1/2} gm ^{1/2} s ⁻¹]
Magnetic flux density (B)	1 Weber/M ² [ks ⁻² a ⁻¹]	0.999670 Int. volt S/M ²	$3.336(10)^{-7}$ Statmaxwell/cm ² [cm ^{-3/2} gm ^{1/2}]	(10) ⁹ Maxwell/cm ² [cm ^{-1/2} gm ^{1/2} s ⁻¹]	(10) ⁹ Gauss [cm ^{-1/2} gm ^{1/2} s ⁻¹]
Inductance (L)	1 Henry [m ² ks ⁻² a ⁻²]	0.999505 Int. Henry	$1.1126(10)^{-12}$ Stathenry [cm ⁻¹ s ²]	(10) ⁹ cm [cm]	(10) ⁹ cm [cm]
Power	1 Watt [m ² ks ⁻²]	0.999835 Int. Watt	(10) ⁷ erg/s [cm ² gms ⁻²]	(10) ⁷ erg/s [cm ² gms ⁻²]	(10) ⁷ erg/s [cm ² gms ⁻²]

each other with a force per unit length, f_l , given by

$$f_l = K_m I_1 I_2 / d.$$

Here the constant of proportionality, K_m , may be chosen quite arbitrarily. The *cgs emu sys-*

tem is based on the dyne and the centimeter as units of force and length and on the choice of K_m as a dimensionless constant of magnitude two. The emu of current, the *abampere*, then has the dimensions of dyne^{1/2}, or cm^{1/2}gm^{1/2}sec⁻¹.

The emu of charge, the *abcoulomb*, is defined as the charge which passes a given surface in one second if a steady current of one abampere flows across the surface. Its dimensions are therefore $\text{cm}^{3/2}\text{gm}^{1/2}$, which differ from the dimensions of the statcoulomb by a factor which has the dimensions of a speed. This relationship is connected with the fact that the ratio $2K_e/K_m$ must have the value of the square of the speed of light in any consistent system of units. It follows further that

$$1 \text{ abcoulomb} = 2.998(10)^{10} \text{ statcoulomb},$$

the speed of light in vacuo being $2.998(10)^{10}$ cm/sec.

A *rationalized emu* system, in which K_m is taken as $1/2\pi$, has also been developed.

The electrostatic system is convenient for problems in which the principal equations may be deduced from Coulomb's law. Similarly, the electromagnetic system is convenient for problems involving the interactions between currents. In many physical problems, both electrical and magnetic interactions take place. Both systems suffer from certain inconveniences under these circumstances, and the *Gaussian* system of units has, as a result, gained wide popularity. In this system, magnetic quantities, such as magnetic field strength and magnetic flux density, are expressed in emu, while electric field strength, charge, and current are expressed in esu. To maintain self-consistency, it is essential that a factor c , the speed of light, be introduced into many of the equations which describe electromagnetic phenomena. Whenever the factor c occurs in equations which employ quantities expressed in simple systems, or in the mixed Gaussian system, it is the speed of light in vacuo, having the dimensions of cm/sec, not a pure number. A *rationalized Gaussian* system is sometimes employed.

In all of the systems discussed thus far, cgs mechanical units have been employed. New systems of electrical units evolve if other sets of mechanical units are substituted. Only two such systems, both based on the mks mechanical units, have found wide acceptance. One of these two is the *rationalized mksa* system. The arbitrary choice which leads to this system is that of the unit of current. The *absolute ampere* is defined as exactly one-tenth of an abampere. With this choice, and with the newton and the meter as the units of force and length, the two constants which were

chosen arbitrarily in the esu and emu systems are determined and have dimensions. They become:

$$K_e = 8.986(10)^9 \text{ km}^2\text{s}^{-2}\text{a}^2,$$

and

$$K_m = 2.000(10)^{-7} \text{ kms}^{-2}\text{a}^2.$$

One virtue of the mksa system is that nearly all of the electrical quantities expressed in it coincide closely with the *practical system* of units which grew up during the nineteenth century. Thus the volt, the ampere, the henry, the farad, and the ohm are all units in the mksa system. In fact, the legal electrical units have been fixed by international agreement since 1950 as the absolute mksa units. Prior to that time, the *International system* of electrical units had been used. This system had been intended to coincide with the absolute system, but had been defined in terms of fixed standards, which are slightly in error. There are therefore small differences between the two sets of electrical quantities, of the order of a few parts in ten thousand.

One more remark needs to be made in regard to the dimensions of certain electromagnetic units. Two electrical quantities, the field strength \mathbf{E} and the displacement \mathbf{D} , are closely related, as are two magnetic quantities, the field strength \mathbf{H} and the flux density \mathbf{B} . In the electrostatic system, \mathbf{E} and \mathbf{D} have the same dimensions and are identical in magnitude in empty space; in the electromagnetic system, \mathbf{H} and \mathbf{B} have a corresponding relation. Thus in air, the electrical properties of which are practically those of empty space, the flux density is identical with the magnetic field strength if both are expressed in emu. The old unit of field strength, the *gauss*, has therefore been used to denote both \mathbf{H} and \mathbf{B} . In an attempt to avoid confusion, the name of the emu unit of \mathbf{H} was changed to the *oersted* about 20 years ago. The gauss had become so well established, however, that it is still used, and its meaning (either oersted or maxwell per square cm) must be judged from context.

The relations among the five systems of electrical units which are employed are displayed in Table 4.

UNITS NOT INCLUDED IN ABSOLUTE SYSTEMS

Although nearly all physical measurements, from those of the dimensions of the universe

to those involving nuclei of atoms, *can be expressed* in terms of the mechanical, thermal, and electromagnetic systems discussed above, many physical quantities *are expressed* in terms not reducible to any of the systems given. During the early development of many parts of science, measurements of the relative properties of various substances were all that were possible or required. Hence terms like specific gravity, specific heat, candle power, and curie have come into the literature of the subject. As the art of measurement progresses, such terms are usually redefined in such a way that they acquire absolute meanings.

Many special systems of units are convenient for particular calculations. Thus, many atomic calculations are facilitated if the electronic charge, the radius of the lowest Bohr hydrogen orbit, and mass of the electron are taken as fundamental units of charge, length, and mass, respectively.

UNIT (OF EQUIPMENT). A group of components which, when operating together, accomplish a specified task: e.g., airborne unit (missile), radar unit, Doppler unit or launching ground-handling equipment.

UNIT ESSENTIAL EQUIPMENT (UEE). That portion of the unit mission equipment for T/O units which is air transportable and required to perform the mission.

UNIT MAGNETIC POLE. A magnetic pole of such strength that it repels a like pole one centimeter away with a force of one dyne.

UNIT MISSION EQUIPMENT (UME). Those items of equipment authorized in the Master Equipment Allowance List (MEAL) or special lists of equipment for specific T/O units as authorized by Headquarters USAF. This equipment will normally be moved with the unit from location to location.

UNITIZATION (UNITIZED DESIGN). In electronic design, the grouping together of functional components into an assembly, often subminiaturized.

UNIVAC. A computer manufactured by Remington-Rand Corporation. The Univac II has a magnetic core storage facility which gives instantaneous access to 24,000 alphabetical or numerical characters. The computer

is equivalent to the machines of the IBM 700 series.

UNIVERSAL MOTOR. A series-wound motor which can be operated on either d-c or single phase a-c.

UNIVERSAL TIME. Time.

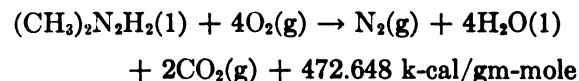
UNIVERSAL TRANSVERSE MERCATOR MAP PROJECTION. A map projection of the surface of the earth on a cylinder tangent to the earth at the equator. Thus, it is accurate only along the equator and its distortion of east-west distances increases so much with increasing latitude that the map is useless in navigation above 70° north or south latitude.

UNRESTRICTED BURNING ROCKET. A solid propellant grain which is designed to burn simultaneously throughout its entire length by holes bored parallel to its axis. The duration of burning is thus very short, and such propellants are used chiefly when great thrust is desired for a short time.

UNRESTRICTED PROPELLANT. Propellant, unrestricted.

UNSTABLE SERVO. Servo, unstable.

UNSYMMETRICAL DIMETHYL HYDRAZINE. An organic base of having the chemical formula, $(\text{CH}_3)_2\text{NNH}_2$. It is a colorless liquid (which tends to turn yellow if exposed to air). It is hygroscopic (2-3% in 24 hours), and fumes in air. Its density is 49.18 pounds/ft³ or 6.85 pounds/gallon (at 77°F). It has a characteristic ammoniacal or "fishy" odor. Its boiling point at 760mm mercury is 63.1°C, freezing point -57.15°C. Its equation of combustion is as follows:



As a liquid it is totally miscible in water, alcohol, ether, benzene and petroleum. In general, Teflon, polyethylene and Kel-F are used as materials of construction. Stainless steel and pure aluminum or alkali-resistant glass are also satisfactory. Most rubbers, either synthetic or natural, are unsatisfactory. In handling this substance, personnel should wear eye goggles, rubber gloves and protective clothing. An ammonia-type cannister gas

mask should also be used. This substance must be stored in a cool place, out of direct sunlight, and caution is to be used in opening any containers to avoid sudden pressure release. It has a low flash point and should therefore be protected from flames and sparks.

UOC. Ultimate Operational Capability.

UP. UNROTATIVE PROJECTILE. A British term used to designate their antiaircraft rockets used on "Z-guns" during World War II. The UP's were four feet in length and 3 inches in diameter, and were propelled by a solid propellant (cordite) grain. They carried an explosive charge of several pounds.

UP-3. A British World War II rocket of the UP type having a 3-inch head and motor. It went into service in 1941. (See **Z-Gun**.)

UPPER AIR. (1) In aerology, all altitudes above 1000 feet. (2) In meteorology, all altitudes above 6 feet (the height of a man making surface observations.)

UPPER ATMOSPHERE. The region of the earth's atmosphere just beyond the **stratosphere** (i.e., beyond about 30 km).

UP-RANGE. The direction from the launching point toward the target.

UP-TIME. The calendar time in which the system is considered in condition to perform its required function.

UP-WASH. The slight upward flow of air just prior to its reaching the immediate vicinity of the leading edge of a rapidly moving airfoil or wing. There is a "damming" of the air under the airfoil; this condensed mass of air forces the newly-arrived mass to flow upward.

UR. Unsatisfactory Report. A term used by Air Force activities to report a field failure or malfunction.

URANIUM. Radioactive element. Symbol U. Atomic number 92.

URANUS. (For data, see **planet**.) The seventh planet of the solar system. To the naked eye Uranus is barely visible as a sixth magnitude star, but in a telescope of moderate aperture the object appears as a disk. The disk has a bluish-green appearance, and no

surface markings have ever been observed. Early observations showed that the planet is very much flattened at the poles, which gives evidence of high rotational speed, but it was not until 1912 that Lowell and Slipher were able to prove, by the **Doppler principle**, that the period of rotation is about 10.75 hours. The relatively high **albedo** and low densities both give evidence of a thick layer of atmosphere about the planet. Reasoning from purely theoretical grounds, on the basis of the mean distance of the planet from the sun, we find that the temperature of the surface of Uranus should be about 63° K. (−345°F.). At such a low temperature all gases except possibly hydrogen, helium, and argon should be condensed out of the atmosphere. However, within recent years, Dunham has shown the existence of a large amount of methane in the atmosphere of Uranus, which indicates that the temperature must be considerably higher than that given by purely theoretical reasoning.

One strikingly interesting characteristic of Uranus is found in the fact that the axis of rotation lies almost in the plane of the ecliptic, being inclined to it by an angle of less than 10°. Furthermore, the direction of rotation is opposite to that of all of the other members of the solar system.

Uranus has five small **satellites** less than 1000 miles in diameter. The orbit planes of these satellites lie close to the plane of the planet's equator, and hence are nearly perpendicular to the plane of the ecliptic. The satellites revolve about the primary in the same directional sense as that in which the planet rotates, i.e., in the retrograde direction.

URSA MAJOR. (The greater bear.) This **constellation** is probably best known for the asterism known in United States as the big dipper and in England as the plough or the wagon. The constellation is circumpolar for both Europe and North America, and two of the stars in the dipper, known as the pointers, are very useful in locating the star **Polaris**, since the line joining them, if extended, will pass close to the celestial pole.

The star Mizar (Zeta Ursae Majoris) at the bend of the handle of the dipper is an easy visual **double star**.

URSA MINOR. (The smaller bear). This **constellation** is best known because of the fact

that the bright star at the end of the handle of the asterism, frequently referred to as the little dipper, is at present the closest bright star to the north celestial pole of rotation. This star **Polaris** (Alpha Ursae Minoris) is described elsewhere. Other than this star the constellation contains very few objects of interest or importance.

USER TEST. A missile or weapon system

test conducted by the ultimate using activity instead of the development or evaluation agency.

USM (UNDERWATER-TO-SURFACE MISSILE). Missile, ground-to-ground; model designation.

USNMTC. United States Naval Missile Test Center; Point Mugu, California.

V

V. (1) Volume (v or V), volume, molecular (V), volume of a cavity or room (V), volume of configuration space (V), volume, total (V), volume, specific (v), volume per unit mass (v), volume of atom or molecule (v or v_m), volume per mole (v , V_m or V), volume, critical (V_c), atomic volume (V). (2) Velocity (v), velocity, linear or partial (v), velocity at time t (v or v_t), velocity, average (v_{av} or \bar{v}), velocity, group (v_g or v), velocity components (v_x , v_y , v_z), velocity initial (v_0), velocity of sound or other waves (v). (3) Vanadium (V). (4) Potential, electric (V), potential difference, steady a-c (V), potential difference, rms or effective (V), potential difference, average (V or V_{av}), potential difference, Peltier (V_p), potential difference, Seebeck (V_s), potential difference, Thomson (V_t), potential difference, average (V_{av}), potential difference, contact or Volta (V_v), potential difference, excitation (V_e), potential difference, maximum (V_m or V_{max}), potential difference (V , V_p or V_{pk}). (4) Inner potential of metals (V or V_i). (5) Ionization potential (V or V_i). (6) Potential energy (V or U or E_p).

V-1. The political and popular designation for the German World War II Buzz Bomb. The designation came from the name *Vergeltungswaffe Eins* (Revenge Weapon One). The official code name for this missile was *Kraehe* (Crow) and its technical identification was Fzg-76 (*Flugzeuge-76*, or Aircraft-76). The engineering work on this missile began in 1942.

The speed of the V-1 was approximately 360-400 mph using a pulsejet motor. The range was 150-200 miles. The missile was launched from a long inclined catapult ramp of cement construction approximately 165 feet long. A hydrogen peroxide steam generator powered the catapult. V-1's were also air-launched from Heinkel-111 bombers. The missile weighed about 5000 pounds at takeoff, about 1000 pounds of this being propellant and 1540 pounds being warhead. It was approxi-

mately 25 feet long, 32 inches in diameter and had a single mid-wing approximately 18 feet in span. The power plant was an Argus Rohr 014 pulsejet 11½ feet long by 22 inches in diameter, pulsing resonantly at 47 cycles per second. The missile flew at a constant altitude of about 2,000-3,000 feet according to instructions of a sensitive altimeter. It followed a pre-set path supervised by a magnetic compass. Fuel supply was cut off by the action of an air log, spinning in the nose of the missile at a calibrated rate determined by the air density at the flight altitude.

The V-1 was first fired tactically against Britain on 13 June 1944. This missile landed approximately 30 miles from London. The second missile fired the following day landed inside the city. Missiles were fired against England and Belgium principally during the 1944-45 period of World War II. In the summer of 1944 England was the principal target and about 30% of all launches were effective. The remaining 60% were destroyed by the air defense effort (including fighters, antiaircraft guns, rockets and barrage balloons), or through failures. In total 8,070 V-1's were launched against England. Of these 2,420 reached London killing 5,864 persons, injuring 17,197 persons and causing minor injury to 23,174 more persons. Official reports credit the V-1 with 24,491 buildings destroyed and 52,293 others damaged. Untold psychological distress was suffered by the civilian populace incident to the incessant danger. In June 1944 the Germans had 8,500 missiles on hand with the ability to produce 1200 monthly. The missile had a great advantage of being equally suited to bad weather launching and this was a tactical consideration in avoiding fighter countereffort. The V-1's used against Belgium were dropped principally into Brussels and Liege.

V-2. The German World War II rocket missile. Officially it was designated as the A-4. The identification V-2 came from the propaganda name, *Vergeltungs Waffe Zwei* (i.e.,

Revenge Weapon Two). The first tactical launching of this missile was against England on 8 September 1944. Within 10 weeks approximately 1000 were fired against London. In total about 2000 V-2's were fired at London with 1230 hitting inside the city. V-2 was supersonic and gave no warning of its approach. The announcement of an attack in London was the characteristic double explosion heard somewhere in the distance (usually!), and the 30-40 feet wide crater (30 feet deep), left after impact.

Between August 1944 and February, 1945, 3000 V-2's were delivered to the field. The principal V-2 factory in Germany was an abandoned salt mine at Nordhausen near the Harz Mountains. Assembly of one missile required about 5000 man hours time. Production at Nordhausen was about 30 units per day. Labor at the plant was mainly "slave" type. This permitted excellent security since the workers could not leave their working area except under guard. A total of 12,000 V-2's were manufactured. Some 4300 were fired against Allied targets, mostly London and Antwerp, but some were also fired against the Remagen bridgehead established by the Americans across the Rhine River.

The characteristics of the V-2 are summarized as follows:

Range 189 miles
Maximum velocity 3466 mph
Impact velocity 1800 mph
Maximum altitude 60.3 miles
Time of flight 3 min 40 sec

Weights

Empty	10,300 lbs
Fueled	28,380 lbs
Warhead	2,230 lbs (60% amatol-40% metal)
Engine	1,000 lbs (less accessories)
Alcohol	8,304 lbs
Lox	10,800 lbs

(Propellants were consumed at a rate of 280 lbs/sec).

Hydrogen peroxide 350 lbs (for steam to drive propellant pumps)

Thrust 60,000 lbs
Length 46 feet
Diameter 5.41 feet (center body); across fins 11.7 ft.

VACUUM. Theoretically a space devoid of matter, practically a region of space in which the atmospheric pressure has been reduced as much as possible with present pumping systems, or as much as is necessary to prevent influence of the atmosphere on processes being carried on within the space.

VACUUM APPROXIMATION. The motion of a rocket computed without consideration of areodynamic forces.

VACUUM TRAJECTORY. Trajectory, vacuum.

VACUUM TUBE. An electronic device consisting of two or more electrodes mounted within an evacuated envelope. It makes use of the principle of thermionic emission. Tubes are classified according to the number of elements within: diode, triode, tetrode, pentode, etc., or by their purpose: beam power, cathode ray, cold cathode, dynatron, magnetron, microwave, rectifier, thyatron, UHF, ballast, etc. They are also identified by a standard method of numbering. For example, a tube 6J7: the first number gives the filament voltage, the letter shows the purpose, and the last number shows the number of working connections. Some tubes are further identified with terminal letters "G" or "GT" which refer to "glass" or "glass tube short size," respectively. (See **electron tube**, and **electron tube circuits**.)

VALENCE. The property of an atom or radical to combine with other atoms or radicals in definite proportions, or a number representing the proportion in which a given atom or radical combines. The standard of reference is hydrogen, which is assigned a valence of 1, and the valence of any given atom or radical is then the number of hydrogen atoms, or their equivalent, with which the given atom or radical combines. Many elements have more than one valence, and their compounds are classified and designated accordingly.

VALLEY BREEZE. On hot days, uneven terrain gives rise to uphill breezes, i.e., from the valley up mountain or hill slopes. This breeze is known as a valley breeze; it is an anabatic wind. With sunset, the breeze dies.

VALVE, FOUR-WAY (PRESSURE-DRAIN-LOAD-LOAD). A hydraulic valve which uses four orifices to control the load flow or

pressure for bi-directional motion. One pair of orifices is used for each direction. Basically, the four-way valve operates as two three-way valves in pushpull. As the movable member moves in one direction the load pressure between one pair of orifices increases while the pressure between the other pair decreases. Because of this push-pull action the four-way valve produces a greater force output, is more linear over a larger range, and is less susceptible to supply pressure variations; it has the disadvantage of increased cost. In servo applications the four-way valve is most commonly used. Four-way valves may be closed center or open center types. (See figure.)

VALVE, RELIEF. An hydraulic or pneumatic system element designed to limit the pressure to a maximum safe value.

VALVE, THREE WAY. A type of transfer valve-actuator combination in which only one valve port is used and the actuator output is achieved by metering the working fluid into or out of only one actuator chamber. The system pressure always acts on the small area of the actuator. Thus if A_2 is twice the area of A_1 , the available control pressure in one half the supply pressure under no load conditions. The load induced pressure is:

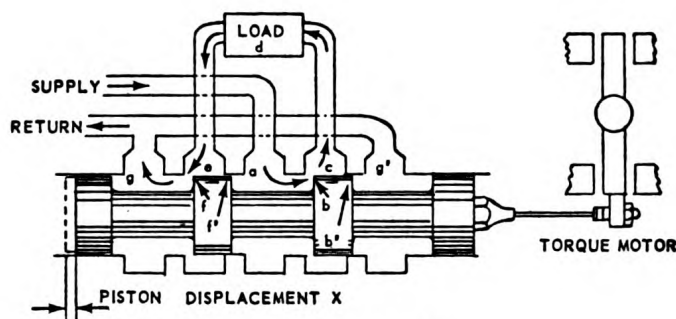
$$P_L = P_c - \frac{P_c}{2} \quad \text{if } P_c = 0$$

(See Figure on Page 661.)

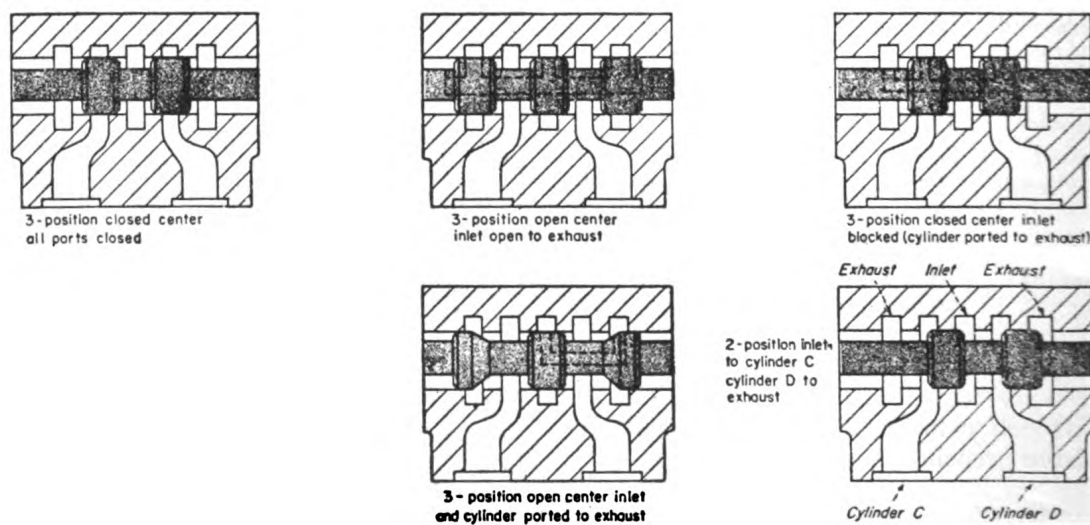
VALVE, TRANSFER. Transfer valve.

VALVE, VENT. Vent valve.

VANADIUM. Metallic element. Symbol V. Atomic number 23.

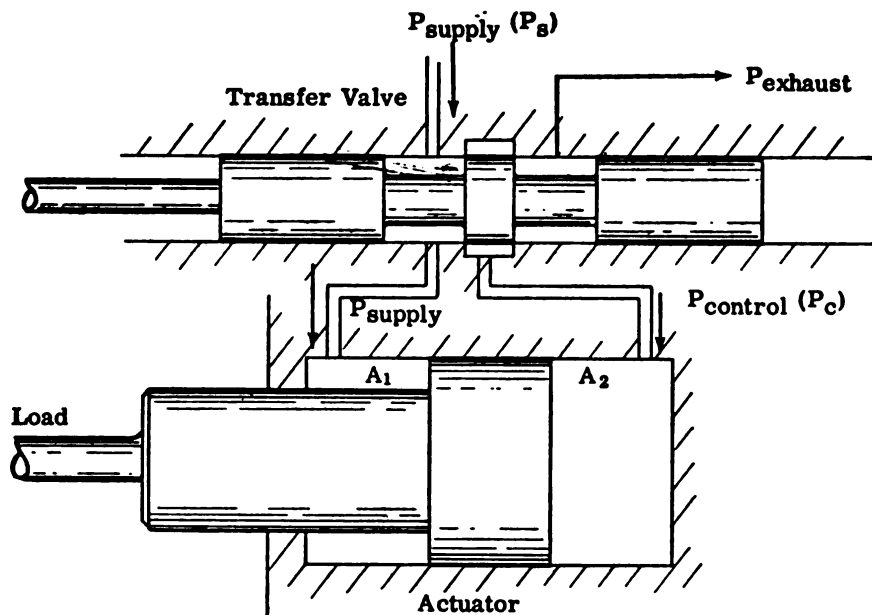


(a) Conventional Four-Way Control Valve



(b) Valve Configurations

Four-way valve schematics.



Three-way valve schematic.

VANE. (1) A thin and more or less flat object intended to align itself with a stream or flow in a manner similar to that of the common weathercock, as: (a) A device that projects ahead of an aircraft to sense gusts or other actions of the air so as to create impulses or signals that are transmitted to the control system to stabilize the aircraft. (b) a fin or stabilizer on a bomb, aircraft, or the like; a fixed or movable surface used to control or give stability to a rocket. (2) A blade or paddlelike object, often fashioned like an airfoil and usually one of several, that rotates about an axis, either being moved by a flow or creating a flow itself, such as the blade of a turbine, of a fan, of a rotary pump or air compressor, etc. (3) Also guide vane. Any of certain stationary blades, plates, or the like that serve to guide or direct a flow, or to create a special kind of flow, as: (a) Any of the blades in the nozzle ring of a gas-turbine engine. (b) Any of the plates or slatlike objects that guide the flow in a wind tunnel. (c) A plate or "fence" projecting from a wing to prevent spanwise flow.

VANGUARD. Project Vanguard was inaugurated officially by President Eisenhower in July, 1956, with the purpose of launching six satellites as part of the American contribution to the International Geophysical Year. This program was proceeding—though on low priority and entirely separated from military

developments—when Sputnik I appeared, changing the entire situation profoundly. In this connection it is of interest to note that during the Sixth International Astronautical Congress in Copenhagen, which convened just after the President's announcement, one of the Russian observers present, the noted scientist Prof. Leonid I. Sedov, stated that the U.S.S.R. also contemplated launching satellites during the IGY.

The Naval Research Laboratory (NRL) was given the responsibility of directing Project Vanguard. The Martin Company became the vehicle prime contractor, having developed the Viking rocket, the prototype of Vanguard's first stage. A new first stage engine, developing 27,000 lb. thrust, was developed by the General Electric Company, while development of the second stage was given to the Aerojet General Corporation, developer of the Aerobee-Hi, prototype of the second stage. Two versions of a third stage, a small solid propellant rocket, were developed, one by Grand Central Rocket Company, the other by Allegheny Ballistic Laboratory. The satellite body (spherical shell) was contracted to Brooks & Perkins, Inc. Responsibility for the instrumentation was assigned to Prof. Van Allen of the State University of Iowa. The Minitrack transmitter system was developed by the Naval Research Laboratory. The Vanguard, like the Explorer, is launched at the Air Force Missile Test Center, Cape

Canaveral, Florida; is radio-tracked by the U.S. Army; is optically tracked under the direction of Prof. F. Whipple, Director of the Smithsonian Astrophysical Observatory; and its orbits are determined by the Vanguard Computation Facility, directed by Dr. P. Herget.

The overall Vanguard vehicle is 72 ft. tall and has a maximum diameter of 45 in. The take-off weight is about 22,400 lb. The shape of the vehicle is very slender. The vehicle has no fins and its single booster engine is unprotected by a structural shell, in order to save weight. The first stage is a modified **Viking** rocket of greatly improved thrust output (about 27,000 lb. for 150 seconds), utilizing liquid oxygen and jet fuel, rather than alcohol as the original Viking series. The fins are removed and stabilization in pitch and yaw is maintained by the swivelled motor. The gimbal mounting of the motor is designed to permit $\pm 5^\circ$ angular deflection of the thrust vector from the center line of the vehicle. Roll stability is attained by means of small tangential jets of decomposed hydrogen peroxide. In order to minimize weight, helium is used for providing the necessary pressurization of the propellant tanks which are integral with the skin of the airframe. The first stage reaches a burnout velocity of about 5,500 ft./sec.

The design philosophy of the second stage is based on the highly successful Aerobee-Hi rocket for high-altitude research. However, the Vanguard stage is in many respects quite different from the **Aerobee**. It is greater in length and diameter. Thrust and burning time are increased by greater propellant loading capacity and by using a more potent propellant combination. The aniline-alcohol fuel used by the Aerobee is replaced by unsymmetrical dimethyl-hydrazine (UDMH). Nitric acid of increased concentration is used as oxidizer. Both propellant components are fed by helium gas pressure from integral tanks. The result of these improvements is that the second Vanguard stage attains more than 10,000 ft/sec compared to about 7,100 ft/sec reached by the Aerobee. Carrying the third stage and the satellite, the second stage reaches a velocity of about 13,000 ft/sec, including the velocity component of the Earth rotation. Ignition of the motor occurs under vacuum conditions (30 nautical miles high), while the Aerobee was ignited on the ground.

Ignition follows immediately after first-stage separation.

The second stage is in many respects of crucial importance for the whole vehicle system. This stage carries the all-inertial guidance system which controls the first and second stage and the mechanism for spinning the third stage prior to separation. The guidance system consists of three gyroscopes, a trajectory deflection (or pitch) programmer, and error sensors which provide the control commands for the first and second stage. The second stage engine is gimbal-mounted, controlling pitch and yaw. Roll control is provided by separate jets. The second stage also carries the master sequence controller for timing the ignition, the cut-off and the stage separation during the flight. The performance of the second stage carries the vehicle up to orbital altitude and provides it with a horizontal velocity of about 14,000 ft/sec at this altitude.

The third stage and the delicate satellite sphere are housed in the nose section of the second stage. Thereby the satellite is protected from the effects of aerodynamic heating during the ascent. The protective shell which costs weight and therefore reduces the performance, is thrown off during flight, immediately after the denser layers of the atmosphere are left behind. This occurs during the second stage propulsion period.

The third stage is an unguided solid propellant rocket, spin stabilized at about 200 revolutions per minute. Thus its attitude is stabilized roughly in the direction of the local horizon, in order to obtain the greatest possible velocity increment, which is of the order of 13,000 ft/sec. The third stage starts spinning shortly prior to separation.

The hull of the third stage reaches satellite status jointly with the spherical, instrument-carrying body proper. Provisions are made, however, to separate the sphere for the purpose of facilitating outer atmosphere research. Since a sphere has no lift, its path in a gas is determined solely by its (known) momentum, the (known) gravitational attraction and the deceleration due to drag. This deceleration is a function of drag and (known) weight. By measuring the change in flight path one can therefore determine the drag. The only unknown in the drag equation of a sphere is the air density which can therewith be computed. Conditions would be considerably

more involved if the body were not a sphere and therefore had an (unknown) drag coefficient and lift coefficient in addition to the unknown air density.

The thin spherical shell of the satellite consists of gold-plated magnesium and measures about 20 inches in diameter. It houses about 10 lb. of instrumentation, including the Mini-track transmitter system which will be discussed below. The total weight of the satellite is approximately 20 lb. or 0.083 percent of the launching weight.

The vehicle launching site is Cape Canaveral, Florida, at $28^{\circ} 28'$ northern latitude. At this point the circumferential velocity of the earth is 1,340 ft/sec., offering a substantial saving in energy if the vehicle is not fired due east.

The vehicle takes off vertically but, after a few hundred feet altitude, begins to tilt in flight direction. Following a zero-lift trajectory a flight path angle of about 45° is reached at burnout of the first stage at 190,000 ft. altitude. The first stage is jettisoned and the second stage ignited. At burnout of this stage the vehicle has left the atmosphere and begins to coast from 120 nautical miles to about 200 nautical miles. The second stage remains attached during this period because it carries the equipment for correct (i.e., horizontal) orientation of the third stage immediately before firing at the summit point, and for imparting to it the rotation required for maintaining directional stability during the third propulsion period, which lasts about 36 seconds and increases the vehicle's velocity to approximately 26,000 ft/sec at 300 miles altitude. Immediately prior to firing the solid-propellant stage, the second stage is separated. After a total period of ascent of about 10 minutes, and 1500 miles down range from the launching point, the third stage, together with the 20-inch sphere, has gained orbital velocity. If desired, the satellite sphere can then be separated.

Due to unavoidable inaccuracies of the guidance system, engine cut-off and operation of the spinning third stage, the Vanguard satellite is unlikely to enter a circular orbit. For this reason no attempt will be made to direct the vehicle into an exactly specified orbit. In order to compensate for the effect of inaccuracies, the vehicle is laid out for higher initial velocity than required to enter a circular orbit (roughly 1,000 ft/sec (velocity ex-

cess)). Indeed, the orbit of Vanguard I (1958) is highly elliptic. (For orbital data, see table in article on **Satellite, Artificial**.) (See illustrations facing Pages 443 and 634.)

VANISHING-MAN CONCEPT. A concept of warfare that visualizes more and more use of robots, machines, and automation with a corresponding use of fewer and fewer men.

VAPOR PRESSURE. The pressure exerted by the vapor of a substance when in equilibrium with the solid or liquid form.

VARIABLE-AREA EXHAUST NOZZLE. On a jet engine, an exhaust nozzle of which the exhaust exit opening can be varied in area by means of some mechanical device, permitting the highest possible jet velocity under given conditions of engine rotational speed, air speed, etc. (Cf. **fixed area exhaust nozzle**.)

VARIABLE FOCUS LENS. A lens system, part of which is movable, and so designed as to have correction for lens **aberrations**, continual sharp focusing of the image on the receiving film and constant **f-value** as the focal length is changed. Such a lens gives the effect of moving the camera towards or away from the object. Variable focus lenses are used in motion picture and television cameras; commonly called Zoomar lenses.

VARIABLE STARS. Any star whose light is known to fluctuate is called a variable star. There is evidence that the ancients noticed certain temporary stars, now known as **novae**, and that the star **Algol** was recognized by them as a variable. The first definite record that we have of observation of a variable star is in connection with observations of **Mira** during the late 16th and early 17th centuries. In 1844, Argelander published the first catalogue of variable stars which contained eighteen entries. The publication of this catalogue stirred up a great deal of interest in variable stars and they became objects of much search and study.

At the present time most variable stars are discovered from examination of photographic plates, taken at different times, of the same region of the sky. At present over 10,000 variables are known, and it is estimated that at least 5% of all stars are at least slightly variable. When a variable star is first ob-

served it is assigned a serial number in order of discovery within the year, together with the year of discovery (e.g., 256, 1923 designates the 256th variable discovered in 1923). After a sufficient number of observations have been taken to confirm the variability of the star and the fact that it is really a discovery, the star is assigned letters, in accordance with a system established by Bayer, followed by the genitive case of the **constellation** within which the object is located (e.g., RZ Herculis). Novae are not included in this system of classification, being referred to by "nova" followed by the genitive case of the constellation and the year of discovery (e.g., Nova Herculis 1934).

When a sufficient number of observations of the magnitude of a variable have been obtained, a light curve is plotted and the study of the characteristics of the object is undertaken. Variable stars divide themselves into two natural groups: the periodic and non-periodic variables. In the variable star diagram the number of periodic variable stars within certain limits of period is plotted as ordinate against the logarithm of the period in days. Examination of the figure indicates that there are three principal groups of periodic variables: one group with periods of less than 1 day, a second with periods between 3 and 50 days, and a large group with periods between 120 and 750 days. Periodic variables with periods under 50 days are known as **Cepheids**, while those with periods greater than 100 days are known as long-period variables. The non-periodic variables are divided into two groups: the novae and the irregular variables.

VARICOUPLER. A radio frequency transformer consisting of a set of coils so arranged as to facilitate a change or variation in the coupling between two interconnected circuits.

VARILOTTER. Trade name for a device which automatically plots or reads a graph by means of a **photocell** system.

VARISTOR. A two-electrode **semiconductor** device having a voltage-dependent, non-linear resistance. The resistance is markedly reduced when the applied voltage is increased. (One of its uses is surge voltage protection.)

VB-1. An Army Air Corps World War II guided bomb. It was gravity powered and

guided by radio in azimuth only. It was also called **Azon**.

VB-3. An Army Air Corps World War II glide bomb, popularly called the **Razon**. It was a gravity powered missile dropped from a high altitude and radio controlled in azimuth and range.

VB-6. An Army Air Corps World War II guided bomb of the homing type (**heat-seeker**), never used in combat. It was popularly called the **Felix**.

VECTOGRAPH. In photogrammetry, a print or transparency in which the two views of a stereoscopic pair are reproduced in terms of polarization rather than image intensity. Such a print examined through polaroid lenses gives the impression of a three-dimensional view.

VECTOR. (1) A quantity possessing magnitude, direction and sense. (2) To position an interceptor with respect to its target through commands issued from a separate control station.

VECTOR RADIUS. Radius vector.

VECTERING ERROR. The radial distance between desired and actual tracks of an interceptor vectored to a target by a separate control station.

VECTERING REQUIREMENT. The boundary loci of tracks within which a given interceptor must pass in order to acquire a given target with its weapons control system and thereafter launch its missiles to obtain the desired probability of kill.

VEERING WIND. Any clockwise change in wind direction is known as veering of the wind. It is opposite of a backing wind.

VEGA. (1) A rocket under development capable of putting a 7400-pound satellite into a 300-mile orbit, or capable of a lunar mission. It is based on an **Atlas** first stage; it has a section of the **Vanguard** as its second stage; and it has a rocket carrying storable fuel, capable of delayed ignition, as a third stage. (2) The second brightest star visible in Northern latitudes. It is in the constellation **Lyra**.

VEHICLE. Specifically, a structure, machine, or device, such as an aircraft or rocket, designed to carry a burden through air or space; more restrictively, a rocket ship or

guided missile. This word has acquired its specific meaning owing to the need for a term to embrace aircraft, rockets, and all other flying craft, and has more currency than other words used in this meaning.

VEHICLE, GLIDE. A hypersonic vehicle with a power boost similar to a long-range ballistic missile but with lifting surfaces to provide an optimum lift/drag reentry in the sensible atmosphere. Contrast with **skip vehicle**. (See **trajectory, glide**.)

VEHICLE, SKIP. A hypersonic vehicle with a power boost similar to a long-range ballistic missile, but with lifting surfaces to provide reentry control. Contrast with **glide vehicle**. (See **trajectory, skip**.)

VELOCIMETER. (1) A device constructed by Sperry Gyroscope Corporation and used to determine accurate acceleration and velocity data on missile flights over short ranges (2-3 miles or so). It was commonly known as the Sperry M-10 Velocimeter. (2) At the Naval Air Missile Test Center, a special continuous-wave, (CW), radar instrumentation used for velocity measurements. It was a CW reflection doppler system used to measure the velocity of the tracked target. Unlike pulse-radar, the signal from the velocimeter is a continuous transmission of a single frequency in the microwave region. When this signal is reflected back from a moving target its frequency is changed by a small amount due to the doppler effect. The shift in frequency is proportional to the velocity of the target.

VELOCITY. (1) The time rate of change of position. Velocity is a vector quantity; a statement of a velocity therefore includes both a magnitude, expressed in units of length divided by time, and a direction relative to some frame of reference. The defining equation for instantaneous velocity is $\mathbf{v} = d\mathbf{x}/dt$, where \mathbf{x} is the vector specifying position relative to an origin and t is the time. (Cf. **velocity, average**.) The origin is located with reference to an inertial frame, commonly axes fixed to the earth. (2) Sometimes loosely used to express magnitude only, i.e., synonymous with speed.

VELOCITY, ABSOLUTE. The highest velocity theoretically attainable, i.e., the **velocity of light**.

VELOCITY, ANGULAR. A quantity relating to rotational motion. While the use of the term "angular velocity" may be extended to any motion of a point with respect to any axis, it is commonly applied to cases of rotation. Its instantaneous value is defined as the vector, whose magnitude is the time rate of change of the angle θ rotated through, for example, $d\theta/dt$, and whose direction is arbitrarily defined as that direction of the rotation axis for which the rotation is clockwise. The usual symbol is ω or Ω .

The concept of angular velocity is most useful in the case of rigid body motion. If a rigid body rotates about a fixed axis and the position vector of any point P with respect to any point on the axis as origin is \mathbf{r} , the velocity \mathbf{r} of P relative to this origin is $\dot{\mathbf{r}} = \boldsymbol{\omega} \times \mathbf{r}$, where $\boldsymbol{\omega}$ is the instantaneous vector angular velocity. This indeed may serve as a definition of $\boldsymbol{\omega}$.

The average angular velocity may be defined as the ratio of the angular displacement divided by the time. In general, however, this is not a vector, since a finite angular displacement is not a vector. The instantaneous angular velocity is more widely used.

Angular velocities, like linear velocities, are vectorially added, for example, if a top is spinning about an axis which is simultaneously being tipped over toward the table, the resultant angular velocity is the vector sum of the angular velocities of spin and of tipping. (This enters into the theory of **precession**.) The derivatives of the **Eulerian angles** are sometimes very useful in describing the angular motion of a rigid body which has components of angular velocity about all its principal axes.

VELOCITY (AT BURNOUT). The velocity of a missile when propulsion ceases; especially important in ballistic and boost-glide missiles.

VELOCITY, CIRCULAR. Circular velocity.

VELOCITY CORRECTION FACTOR. The ratio of actual exhaust velocity to theoretical exhaust velocity.

VELOCITY, ELLIPTIC. Elliptic velocity.

VELOCITY, ESCAPE. Escape velocity.

VELOCITY, HYPERBOLIC. Hyperbolic velocity.

VELOCITY LIMITING SERVO. Servo, velocity limiting.

VELOCITY OF LIGHT, VALUE OF. The best value in 1941, according to Raymond Birge, was 2.99776×10^{10} cm sec⁻¹.

VELOCITY OF SOUND. The velocity with which the phase of a sound wave is propagated. The velocity of sound in dry air is (331.4 meters per second) $\sqrt{T/273.16^\circ\text{K.}}$, where T is the temperature in degrees absolute (Kendall).

VELOCITY, ORBITAL. The velocity at which a body orbits; e.g., the minimum velocity at which an object or vehicle can maintain an orbit about the earth or other celestial body. Specifically, the velocity of a satellite missile which circulates indefinitely around the earth and outside its atmosphere.

VELOCITY, PARABOLIC. Parabolic velocity.

VELOCITY PRESSURE. The total pressure minus the static pressure. It is generally measured by a pitot tube.

VELOCITY PROFILE. The graphical representation of the vectors representing fluid flow at various points along a reference line in the fluid. This reference line is usually perpendicular to the direction of flow. Since viscosity tends to retard flow near the wall of a chamber, the velocity vectors there are of smaller magnitude, thus giving a shape or profile to the vector heads when taken all together.

VELOCITY, RELATIVE. The relative velocity of a point with respect to a reference frame is the time rate of change of a position vector of that point with respect to the reference frame.

VELOCITY SHOCK. The shock condition occurring in equipment when a sudden change occurs in the linear velocity, or in the direction of motion, of the equipment or its mount. (See *shock*; *shock motion*.)

VELOCITY THRUST. The component of total thrust of a rocket motor due to the acceleration of the hot gases passing through the exhaust nozzle.

VELVET GLOVE. A Canadian air-to-air missile project.

VENTURI METER. A flow meter for liquids or gases utilizing the Venturi principle. A tapered constriction is placed in the pipe, and the pressure difference taken between a point in the pipe before the constriction begins, and a point in the throat, or the narrowest part of the constriction. The observed pressure difference is a function of the rate of flow and may be calibrated or calculated to obtain flow rates. For the principle of the Venturi meter, see *Bernoulli law*.

VENT-VALVE. A valve used in a hydraulic/pneumatic system to provide a means for bleeding or venting the container.

VENUS. (For data, see *planet*.) The second planet in the solar system. Venus is much like the earth. This planet is one of the most conspicuous objects in the sky and may easily be viewed in full daylight with the naked eye, provided attention is directed to the proper point in the heavens. For this reason Venus is frequently used by navigators for obtaining a *Summer line* in the daytime to use in conjunction with an observation of the sun. At inferior conjunction Venus is closer to the earth than any other astronomical object except the moon (and an occasional asteroid or comet), having a distance of only 26,000,000 miles. Since at superior conjunction the planet has a distance of nearly 160,000,000 miles the changes in apparent diameter are very great and, as a matter of fact, Venus appears the brightest to us (i.e., has the largest apparent area) when in the crescent phase similar in shape to the moon when about 5 days old.

Telescopically Venus is not a particularly interesting object except insofar as the phase changes are interesting. There are very few and very faint surface markings; in fact, the markings are so faint and so illusive that the determination of the rotation period of the planet by direct observation is practically impossible. The application of the spectroscopic, by applying the *Doppler-Fizeau principle* to the spectral lines, indicates that the rotation period is considerably longer than that of the earth, 30 days being a fair compromise between various discordant results.

The high reflecting power of Venus, coupled with its gravity close to that of earth, lead to the conclusion that Venus has a dense atmosphere. A tremendous amount of research has

been applied to the problem of the constitution of the atmosphere of Venus. Delicate and exacting tests have failed to indicate the presence of either water vapor or oxygen in the atmosphere of Venus, although there is considerable evidence of the existence of carbon dioxide. The absence of water vapor precludes the possibility of any large bodies of water on the planet and makes the existence of any forms of life such as we know them on the earth highly improbable. Spectroscopic evidence shows the presence of a surprisingly high concentration of carbon dioxide in the atmosphere of Venus.

Comparatively little is known concerning the surface conditions of Venus because the dense atmosphere of the planet prevents observations being made of the surface. Measurements of the surface temperature of the planet indicate a range of from 333°K. (140°F.) on the sunlit portions, down to 253°K. (−4°F.) for the dark regions.

VENUSIAN PROBES. Planetary probes.

VERY HIGH FREQUENCY. A frequency in the range 30-300 megacycles per second.

VERY LOW FREQUENCY. A frequency in the range 10-30 kilocycles per second.

VERNAL EQUINOX. The intersection of the ecliptic and the celestial equator when the sun travels north in the spring. It is also called the "first point of Aries." It was chosen as a fixed point in the heavens to correspond to Greenwich on the earth, and is used as a reference for measuring celestial position.

VERNIER. A device, especially a measuring device, having a fine adjustment capable of precise estimation or regulation of a quantity.

VERNIER CUT-OFF. A technique of propulsion in which the main motor thrust is diminished to some much smaller value during the final seconds of burning. During this time a precise determination of missile position, heading, and attitude is made and corrections preparatory to final motor cut-off. Cut-off at the lower acceleration derived from the smaller thrust thus provides better control of final velocity.

VERNIER ENGINES. Rocket engines (usually liquid) used to adjust the final velocity of

a long-range ballistic missile. The engines are also used to correct heading errors.

VERSITRON. A low-noise amplification device announced in 1957 by Advance Industries Inc.

VERTICAL CIRCLE. Any great circle on the celestial sphere which passes through the zenith and nadir is known as a vertical circle. Since the zenith and nadir are poles of the horizon, a vertical circle must be perpendicular to the horizon. The vertical circle which cuts the horizon at the north and south points is known as the local meridian, while that vertical circle which cuts the horizon at the east and west points is known as the prime vertical.

VHF. Abbreviation for very high frequency, the band of frequencies between 30 and 300 megacycles.

VIBRATION(S) AND WAVES. These terms are used in very broad senses and apply to a large variety of phenomena and processes. "Vibration" commonly refers to a to-and-fro motion. Its meaning is often broadened to include any periodic physical process, such, for example, as a cyclic variation in electric or magnetic field intensity. When an elastic body is deformed and released, it is in general set into oscillation such that the displacement of any particle from its equilibrium position is a more or less complicated harmonic function of the time. The vibration may or may not be symmetrical with respect to the neutral position; in any case the maximum displacement is called the amplitude of the vibration. By analogy, the same terms and the same analysis are applied to vibrations of any type.

VIBRATION CONTROL. In missile flight, low-frequency vibrations frequently arise, being accentuated by the long, slender configuration of most missiles. There are also higher frequency vibrations arising from the operation of the power plant. In an effort to control the effects of vibrations, particularly to avoid their intensification by resonance, missile components which are sensitive to vibration effects (such as gyros, stabilized platforms, accelerometers, etc. are mounted at the nodes of natural vibrations. To determine these nodal points, the missile is hung

from a resilient support and set into vibratory motion by a small exciter. Installation locations are then sought where minimum amplitude of motion is experienced.

VIBRATION, FORCED. Vibration of a body resulting from application of external force during an explicit time interval.

VIBRATION, FREE. Vibration of a body occurring without external forces being applied during the time the phenomenon is occurring.

VIBRATION, NATURAL MODE OF. The set of amplitude ratios and phase differences in a system undergoing free vibrations at a single natural frequency.

VIBRATION, STEADY-STATE. Vibration in which the motion of every body in the system is periodic.

VIBRATION TESTING OF COMPONENTS. The vibrations at various points in a missile in flight are recorded by **telemetry** methods. The recordings are then played back into electromagnetic shake tables in the testing facility to evaluate performance of components, or complete missiles.

VIBRATOR. A magnetically-operated, switch mechanism used to "chop" d-c into essentially square waves of a-c for the purposes of **transformation**. Two types are encountered in radio service; non-synchronous and synchronous. The non-synchronous vibrator merely performs the d-c to a-c conversion as mentioned above, while the synchronous vibrator is equipped with an additional set of contacts operating in synchronism with the first. The second switch set is used to convert the a-c, after transformation, back to d-c.

VIBRATRON. A resonant oscillator used to modulate telemetry transmitters proportional to measured quantity.

VIDEO. A term pertaining to the bandwidth and spectrum position of the signal resulting from television scanning. In current usage, video means a bandwidth of the order of megacycles, and a spectrum position that goes with a d-c carrier.

VIDEO AMPLIFIER. An electronic device which provides wide band operation in the frequency range from approximately 15 cycles

per second to 5 megacycles per second. It is used to give a signal of sufficient intensity to modulate a cathode-ray tube (either by intensity modulation or deflection modulation, according to the type of display used), or to operate some auto-following or other special circuit.

VIDEO FREQUENCIES. Frequencies existing in the demodulated output of a television camera as a result of scanning the image being transmitted. The range is from almost zero to well over 4 megacycles. Video frequencies are also termed visual frequencies.

VIDEO-FREQUENCY AMPLIFIER. Amplifier, video-frequency.

VIDICON. A camera tube (see **tube, camera**) with a photoconductive **mosaic**. In other aspects, the tube is similar to an **orthicon**.

VIKING. An American high-altitude research rocket patterned after the German V-2. It was developed under the U.S. Navy, by the Glenn Martin Company. In 1952 it attained the then world's record for altitude and speed for a single-stage rocket; 136 miles altitude and 5,000 miles per hour velocity. The first Viking flight was made on 3 May 1949. This rocket reached an altitude of 51½ miles. One Viking was launched at sea from the U.S.S. Norton Sound in 1950. The missile was designed originally for a 200 mile altitude, but reached 135 miles with a 425 pound payload. In 1952, the missile was redesigned, and its length decreased to 45 feet and its diameter increased to 45 inches. Propellant capacity was increased. Viking #7 was fired in August 1951, and was the first rocket to exceed the V-2's record of 116 miles.

The vehicle was changed radically during the program. Viking #7 was 32 inches in diameter, 48.6 feet in length, and weighed approximately 10,000 pounds. Viking #10 was 42 feet long. The motor had a thrust of 20,000 pounds, and used alcohol and liquid oxygen as propellants. The Viking used a swivelling motor for control in pitch and yaw, and corrected for roll by a hydrogen peroxide tangential jet system. Objectives of the Viking tests were the determination of: atmospheric temperatures, pressures, densities, and compositions, nature and properties of the **ionosphere**, solar, terrestrial and cosmic radiations and the physics of high energy particles.

Vikings #9-#11 were all approximately 42 feet long, 45 inches in diameter, weighing about 15,000 pounds at take-off, with 12,000 pounds of propellants. Payload was 750 pounds, and motor thrust 20,500 pounds. Viking #11 was fired at White Sands Proving Ground on 24 May 1954, reaching an altitude of 158 miles.

The Viking #12 was fired at Patrick Air Force Base (actually Cape Canaveral) on December 8, 1956, as the first vehicle of the **Vanguard** program. (See **missile, guided**.) (See also illustration facing Page 443.)

VIRGO. Virgo, the sixth sign of the zodiac, is one of the earliest-named among the constellations. Astronomically, the constellation is famous for the large number of **nebulae** found in it. Sir William Herschel found no less than 323 of these objects in this part of the sky and more recent observations have raised the number to over 500. A large number of variable stars are also to be found in the constellation. The brightest star in the constellation is the well-known star Spica.

VISCOSITY. The phenomenon of the generation of stresses in a fluid by the distortion of fluid elements by the flow. The stresses act to oppose the distortion and to dissipate energy. The term is usually taken to mean a Newtonian viscosity.

VISIBILITY. That greatest distance toward the horizon at which an unaided normal eye can clearly distinguish prominent objects without aid of optical devices. In measuring visibility, officially, it is necessary that the value given exist over more than one-half the horizon.

VISION, PERSISTENCE OF. The sensation in the retina does not cease at once when the stimulus is removed. For a brightness of about a **candle** per square meter, the critical frequency beyond which no **flicker** may be detected is about 30 times per second. The limit, however, depends greatly on the conditions of observation, and particularly on the **brightness alternation**.

VISUAL BINARIES. A visual **binary star** is one for which the angular separation between the **two components** is great enough to permit the system to be observed as a **double star** in a telescope. The resolving power of the

telescope employed is an important factor in the detection of a visual binary and as telescopes of larger and larger aperture are built there will be an ever increasing number of visual binaries discovered. Also, the brightness of the objects is an important factor in the detection of the double character of a star, it being easier to see as separate objects two faint stars separated by a small angular distance, than two bright stars separated by the same angular distance. Adopting certain arbitrary definitions as to what shall be considered a visual binary, Aitken estimates that about 1 star out of every 18 is a visual binary.

Visual binary stars are studied from observations taken either with a filar micrometer or a stellar interferometer. The brighter star of the pair is known as the primary and the fainter as the secondary. The position angle of the secondary with respect to the primary is measured, together with the angular distance between the two components. The time of the observation is also recorded. After a sufficient number of observations have been obtained they are plotted in polar **coordinates**, using the primary star as origin. Through these plotted points the most probable ellipse is drawn, the only restriction on the ellipse being that the Keplerian Law of Areas must be satisfied. The ellipse thus drawn is known as the apparent ellipse.

This apparent ellipse is the projection of the actual elliptical **orbit**, of the secondary with reference to the primary, on the plane perpendicular to the line of sight of the observer. From this projected ellipse the complete elements of the orbit may be computed, the semi-major axis, a , being expressed in angular units unless the stellar parallax of the system is known.

VISUAL INSPECTION. *Inspection, Visual.*

VOLTAGE DIVIDER. A network used for the purpose of tapping a fractional part of the electrical potential difference existing between the input terminals.

VOLTMETER(S). The usual instruments of this class differ from **ammeters** used on the same type of service in only one essential respect: they are of very high resistance. Therefore, when connected across the terminals between which the voltage is to be measured, they take very little current and cause but a very slight drop in the potential differ-

ence. The current through the voltmeter is proportional to the voltage, and the scale may therefore be graduated to read directly in volts. Instruments are made which, with the proper change in connections, serve either as voltmeters or ammeters, the scale having two gradations. For high voltages, the voltmeter is placed in series with a large resistance, called a multiplier, so that the potential difference between its terminals is a known fraction of the voltage under test.

There are electrostatic voltmeters which may be used to measure electrostatic potentials of thousands of volts. A common form resembles a gold-leaf **electrometer** of large size, but with a brass pointer swinging on a scale in place of the gold-leaf.

VOLTMETER, VACUUM-TUBE. Commonly a very high input impedance **voltmeter**, utilizing the power gain of a **vacuum tube** for operating a suitable meter movement without loading the source of the voltage to be measured.

VOLUME UNIT (VU). A quantitative expression for volume in an electric circuit. The volume in vu is numerically equal to the number of decibels which expresses the ratio of the magnitude of the waves to the magnitude of reference volume.

VORTAC. A system of air traffic control scheduled to be adopted in the United States by 1960 for the control of both military and civilian aircraft. It involves the distance measuring and directional navigation services necessary to an aircraft pilot to safely fly his plane. It uses very high frequency omnidirectional **radio range (VOR)**, and **distance measuring equipment (DME)**, used by the military. The military **TACAN** (tactical air navigation), system will be retained for DME, and VOR will be used for directional purposes.

VORTEX LINE. (1) A line everywhere parallel to the local direction of the **vorticity**. In an incompressible, inviscid fluid, vortex lines are convected by the fluid. (2) A line of concentrated **vorticity** such as are found trailing from the free end of an **aerofoil**. Since vorticity is a solenoidal vector, the direction of the vorticity is parallel to the line.

VORTEX MOTION. The motion of a fluid with non-zero **vorticity**. We may distinguish:

(1) Motion in which the vorticity is confined to small regions of space, i.e., **aerofoil and boundary layer theory**, motion of isolated vortices. (2) Motion in which the vorticity is everywhere nearly the same, i.e., **small perturbations of a uniformly rotating fluid**. (3) Viscous motion. (4) Randomly distributed vorticity, i.e., **turbulent motion**.

VR TUBE. In electronics, a **voltage regulating tube**. Normally they are diodes filled with neon or argon. VR tubes are identified by numbers such as VR 105-30. In this case VR denotes voltage regulation, 105 is the rated voltage between cathode and plate, and 30 is the maximum current which the tube can carry.

V-T DIAGRAM. A velocity-time diagram, as used to solve problems of the motion of a particle. It is a form of **hodograph**. If velocities are plotted against time on such a diagram, the integrated area from t_1 to t_2 is equivalent to the distance travelled by the particle.

$$s_{12} = \int_{t_1}^{t_2} v dt \quad (\text{See Figure 1.})$$

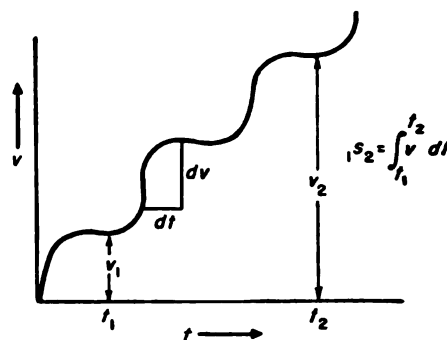


Fig. 1. V-t diagram.

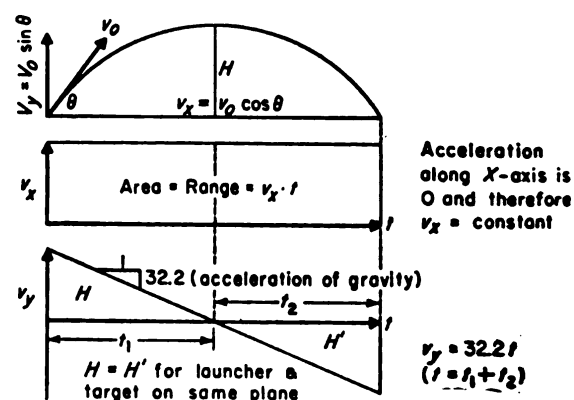


Fig. 2. V-t diagram.

The v-t diagram can be used to compute trajectory information if one v-t diagram is produced for each component of velocity. Figure 2 shows the trajectory of a missile, and the two v-t diagrams relating to its motion in the x and y directions.

V-T FUZE. Variable time fuze. It is the so-called "proximity fuze." This fuze contains a small radio transmitting and receiving set in a plastic nose, which can be attached to artillery shells. When the projectile is fired,

the radio set's battery is automatically charged by breakage of the acid flask. The fuze operates on the radar principle of the returning echo.

VTOL. A type of aircraft having a vertical takeoff and landing.

VU. Volume unit.

VULNERABILITY. The susceptibility of a target to a damage agent.

W

W. (1) Work (w or W). (2) Net work function, electronic (w), gross work function, electronic (w_g). (3) Water vapor content (w). (4) Watt (w). (5) Radiant flux density, or irradiance (W). (6) Tungsten (wolfram) (W). (7) Flow rate (w). (8) Linear yaw velocity (w). (9) Web thickness (propulsion) (w). (10) Weight (W).

WAC CORPORAL. A small, high-altitude rocket missile. It was 16 feet in length, 12 inches in diameter; it had a takeoff weight of 665 pounds and, when fired with **Tiny Tim** booster, reached an altitude of 43½ miles. The WAC Corporal was used as the second stage to the German V-2 in the **Bumper Project**. Work on a ground-to-air missile was begun in 1944 at California Institute of Technology, and in 1945 the WAC Corporal was produced. Thrust for the WAC Corporal was furnished by a nitric acid-aniline Aerojet General engine. The WAC Corporal was first fired in September 1945. The original specifications for the vehicle included a 19-mile ceiling; this was greatly exceeded in the first firing, which reached 43½ miles. The vehicle carried a 25-pound payload. Its dimensions were: length, 192 inches; diameter, 12 inches; fin span, 48 inches; weight of airframe, 272 pounds; weight of propellant, 444 pounds; and payload, 25 pounds.

WADC. Wright Air Development Center; Wright Patterson Air Force Base; Dayton, Ohio.

WAGTAIL. A U.S. Air Force air-to-ground missile developed by the Minneapolis-Honeywell Aeronautical Division. No details were announced.

WAIVER. A contractual agreement to permit acceptance by the Procuring Agency of an end item or equipment which does not conform to the applicable specification and/or drawings. (Contrast with **deviation**.)

WAKE. (1) In general, the region behind a body moving through a fluid, within which

most of the effects of the body on the motion of the fluid are concentrated. (2) The turbulent volume of gas enclosed by the boundary layer, and originating from the base of a missile.

WAMOSCOPE (WAVE MODulated oscilloscope). A cathode ray tube system including detection and display of a microwave signal in a single envelope amplification, thus eliminating the local oscillator, mixer, IF amplifier, detector, video amplifier and associated circuitry in a conventional radar receiver. Tubes are available for the range of 2000 to 4000 megacycles.

WANTON. A test range term used to describe a malfunctioning missile.

WARHEAD. The effective military payload carried by a missile. It may consist of high explosives, chemicals, biological agents, fissionable materials, atomic devices, thermonuclear devices or other effective materials. The term warhead refers to the damage producing elements of the payload, i.e., casing, effective agent, power supplies, etc. When supplemented by a fuze and safety-and-arming mechanism the warhead is part of the missile **armament system**.

WARHEAD, BLAST. A warhead designed primarily to convert its latent energy to a source of high pressure which is propagated away from the original warhead position. Damages targets by subjecting the target surface or structure to extreme **overpressure**.

WARHEAD, BLAST CLUSTER. A number of sub-warheads, or sub-missiles, carried by a parent warhead or missile each of which is in itself a missile equipped with a full complement of armament.

WARHEAD BOOSTER. The end element of an explosive train whose detonation initiates the warhead detonation.

WARHEAD, FRAGMENTING. A warhead specifically designed to emit a maximum num-

ber of specially shaped fragments having optimum propagation properties. The blast effect which accompanies the emission of the fragments is a secondary effect and is not generally considered in the assessment of the effectiveness of the fragmenting warhead.

WARHEAD GAIN. The increase in damage effectiveness of a non-isotropic warhead achieved by enhancing the effects in particular directions at the expense of other directions.

WARHEAD, ISOTROPIC. A warhead whose damage effect is the same in all directions:

Max. range of isotropic fragmentation
 $\text{warhead} \simeq \sqrt[3]{\text{warhead weight}}$

Max. range of isotropic blast warhead
 $\simeq \sqrt[3]{\text{warhead weight}}$

WARHEAD PATTERN. A description of the relative angular variation of the damage parameter of a non-isotropic warhead. The warhead pattern is the spatial distribution of some significant warhead-damage or emission parameter in a particular set of coordinates and in a particular environment.

WARHEAD YIELD. The energy release of a nuclear weapon, usually expressed in kilotons (1,000 tons) of TNT equivalent.

WASH. In aerodynamics, a disturbance in the air produced by the passage of an airfoil. It is also called the **wake** in the general case for any solid body.

WASH IN. In aerodynamics, a permanent warp of the wing tips of an airfoil intended to increase the angle of attack toward the tips.

WASH OUT. In aerodynamics, a permanent warp of the wing tips of an airfoil intended to decrease the angle of attack toward the tips.

WASHBOARD COURSE. A generic term applied to roads and test areas used to evaluate equipment when subjected to a rough and irregular, but known road characteristic.

WASP. A small solid-propellant rocket made by the Cooper Development Company. (See missile, guided.)

WASSERFALL. A German World War II surface-to-air missile having the appearance of a small V-2 with cruciform wings mounted at the midsection. It was developed in 1943 at Peenemunde, using the A-5 and A-7 designs as models. A total of 44 test firings were made. The missile was guided by radio command, through visual observations of its flight. A 17,000 pound, visol-nitric acid motor was used. Missile dimensions were: length, 25.7 feet, diameter, 2.66 feet, fin span, 8.2 feet, wing span, 7.8 feet, total weight, 7,800 pounds, weight of propellant, 4,340 pounds, payload, 675 pounds, thrust, 17,160 pounds for 40 seconds, maximum velocity, 2,165 feet per second. The propellants were fed by a pump driven by an auxiliary motor burning a part of the propellant charge. For control, both exhaust vanes and air rudders were used. The Wasserfall was launched from a platform similar to that used for the V-2's. The missile was designed for a range of 31 miles and an altitude of 50,000 feet.

WATER DELUGE SYSTEM. A high-capacity, high-pressure water system at the test and launch stands for washdown, fire prevention, and fire fighting.

WATT. A unit of power, abbreviation W or w. The rate of energy consumption or conversion when one joule of energy is consumed or converted per second.

WAVE. A disturbance which is propagated in a medium in such a manner that at any point in the medium the displacement is a function of the time, while at any instant the displacement at a point is a function of the position of the point. Any physical quantity which has the same relationship to some independent variable (usually time) that a propagated disturbance has, at a particular instant, with respect to space, may be called a wave. In this definition, displacement is used as a general term, indicating not only mechanical displacement, but also electric displacement, etc. In short, a wave is a time-varying quantity which is also a function of position; for example, any time-varying voltage or current in a network is often called a wave. Other examples of waves are: (1) wave on the surface of a liquid, in which the disturbance is the displacement of any particle in the surface from its equilibrium position; (2) acoustic wave, in which the disturb-

ance is the change in pressure from its equilibrium value at any point in a material medium (fluid or solid); (3) electromagnetic wave, in which the disturbance is the change in the electric and magnetic field intensities from their equilibrium values in space. The first two types are known as mechanical waves, since the propagated disturbance involves motion of a medium.

WAVE, CIRCULATORY-POLARIZED. An electromagnetic wave for which the electric and/or the magnetic field vector at a point describes a circle. This term is usually applied to transverse waves.

WAVE, COMPRESSIVE. Shock Wave.

WAVE(S), DAMPED. A term ordinarily used to designate electric waves which decrease in **amplitude** with time. In any oscillatory circuit which contains resistance (and all practical ones will) the oscillations will be dissipated in resistance losses, and the amplitude of the oscillations will gradually decrease unless energy is continually added to the circuit. When energy is added to overcome this dissipation and maintain the amplitude constant, continuous waves result. A **capacitor** discharging through an **inductance** will give rise to damped waves, and this was the basis of the old spark radio transmitters where the spark gap initiated the discharge and the oscillations continued until all the energy had been dissipated. Since these waves are not as effective for radio transmission as the continuous waves, and since they give rise to interference by virtue of their broad frequency band, they are no longer used for this purpose.

WAVE, DIFFRACTED. When a wave in a medium of certain propagation characteristics is incident upon a discontinuity or a second medium, the diffracted wave is the wave component that results in the first medium in addition to the incident wave and the waves corresponding to the reflected rays of geometrical optics.

WAVE, DIRECT. The wave which travels from the transmission source to the point of reception without reflection or refraction.

WAVE, DOMINANT. The guided wave having the lowest cut-off frequency. It is the only wave which will carry energy when the

excitation frequency is between the lowest cut-off frequency and the next higher cut-off frequency of a **waveguide**.

WAVE, DRAG. Drag.

WAVE, ELECTROMAGNETIC. A wave characterized by variations of **electric** and **magnetic fields**. Electromagnetic waves are known as radio waves, heat waves, light waves, etc., depending on the frequency.

WAVE FRONT. A surface at all of whose points the **phase** of the wave has the same value at a given instant. Wave propagation can be thought of as the motion of a wave front through a medium.

WAVE, GROUND. The waves formed in the ground by an explosion. Ground waves are of three types: *longitudinal* waves (compression), *transverse* waves (shear), and *surface* waves (similar to water ripples). They can be induced by direct ground shock (as in a ground or sub-surface burst) or by blast transmitted through the air (as in any type of burst).

WAVE, GROUND-REFLECTED. A wave reflected one or more times from the earth's surface before reaching the point of reception.

WAVE, INCIDENT. A wave which impinges upon a discontinuity, i.e., upon a medium having different propagation characteristics from those of the original medium.

WAVE, PLANE-POLARIZED. At a point in a homogeneous isotropic medium, an **electromagnetic** wave whose **electric field vector** at all times lies in a fixed plane which contains the direction of **propagation**. (See also **sound wave**, **plane-polarized**.)

WAVE, REFLECTED. When a wave in a medium of certain propagation characteristics is incident upon a discontinuity or a second medium, the wave component that results in the first medium in addition to the incident wave.

WAVE, REFRACTED. That part of an incident wave which travels from one medium into a second medium.

WAVE, SAWTOOTH. A periodic wave whose amplitude varies, substantially linearly

with time, between two values, the interval required for one direction of progress being longer than that for the other.

WAVE, SQUARE. Square wave.

WAVE, STANDING. A wave disturbance which is not progressive, i.e., one in which any component of the field can be specified as a function of position multiplied by a sinusoidal function of time. Standing waves result from the superposition of two waves traveling in opposite directions, having identical amplitudes and frequencies. Thus, if two plane waves, both having amplitudes A wavelength λ , and frequency f , are traveling in opposite directions along the x -axis, their combined effect at the position x and at time t is

$$y = A \sin 2\pi \left(\frac{x}{\lambda} - ft \right) + A \sin 2\pi \left(\frac{x}{\lambda} + ft \right)$$

$$= 2A \sin \frac{2\pi x}{\lambda} \cos 2\pi ft$$

The points $x = n\lambda/2$ (n an integer), at which $\sin 2\pi x/\lambda = 0$, show no disturbance and are known as **nodes** (1). The disturbance is maximal at $x = (2n + 1)\lambda/4$, and such points are called **antinodes** or **loops**.

WAVE(S), SURFACE. (1) Waves of distortion on the free surface separating two fluid phases, usually a liquid and a gas or vapor of low density. The waves are classed as gravitational waves or ripples, depending on whether gravity or surface tension is the controlling force in their motion. (2) An electromagnetic wave component traveling parallel to the earth's surface. (Also called the ground wave.)

WAVE TRAIN. The series of waves produced by a "vibrating" body is called a train of waves.

WAVE, TRANSVERSE. A wave in which the direction of displacement at each point of the medium is parallel to the equiphase surface.

WAVE, TRANSVERSE ELECTRIC (TE WAVE). In a homogeneous isotropic medium, an electromagnetic wave in which the electric field vector is everywhere perpendicular to the direction of propagation.

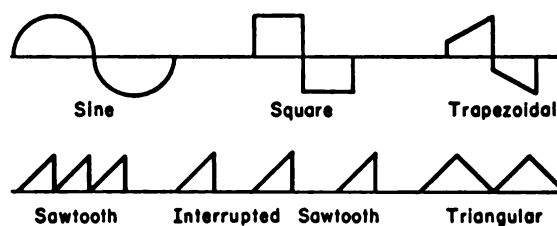
WAVE, TRANSVERSE ELECTROMAGNETIC (TEM WAVE). In a homogeneous isotropic medium, an electromagnetic wave in which both the electric and magnetic field vectors are everywhere perpendicular to the direction of propagation.

WAVE, TRANSVERSE MAGNETIC (TM WAVE). In a homogeneous isotropic medium, an electromagnetic wave in which the magnetic field vector is everywhere perpendicular to the direction of propagation.

WAVE TRAP. A resonant circuit designed to dissipate the energy of one frequency or a frequency-band, while passing all others.

WAVE, TRAVELING PLANE. A plane wave each of whose frequency components has an exponential variation of amplitude and a linear variation of phase in the direction of propagation.

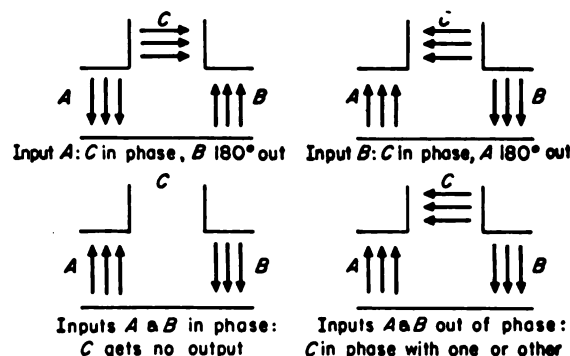
WAVEFORM. In a specific usage in communications, a current or voltage considered as a function of time in a rectangular coordinate system. (See figure.)



Waveforms.

WAVEGUIDE. A system of material boundaries capable of guiding waves.

WAVEGUIDE JUNCTION. A point or region in a waveguide at which provision is made for the flow of energy in two or more directions. (See figure.)



Waveguide junctions.

WAVEGUIDE MODE OF PROPAGATION.

A form of propagation of guided waves that is characterized by a particular field pattern in a plane transverse to the direction of propagation, which field pattern is independent of position along the axis of the waveguide. In the case of uniconductor waveguides, the field pattern of a particular mode of propagation is also independent of frequency. (See figure.)



Typical waveguide modes of propagation.

WAVEGUIDE SWITCH. A waveguide component capable of switching waveguide power from one branch to another.

WAVEGUIDE, TRANSFORMER. A device, usually fixed, added to a waveguide for the purpose of impedance transformation.

WAVEGUIDE TUNER. An adjustable device added to a waveguide for the purpose of impedance transformation.

WAVEGUIDE TWIST. A waveguide section in which there is a progressive rotation of the cross section about the longitudinal axis.

WAVELENGTH. Of a periodic wave in an isotropic medium, the perpendicular distance between two equiphase surfaces in which the displacements have a difference in phase of one complete period. Otherwise phrased, the wavelength is the "space period" of a wave, i.e., the least translation distance that leaves the wave invariant.

In a harmonic wave the wavelength is the distance between any two points at which the phase at the same instant differs by 2π , specifically if the wave is a plane harmonic wave in the x -direction with angular frequency ω , so that the disturbance has the form

$$\sin(\omega t - kx)$$

the wavelength is

$$\lambda = 2\pi/k = 2\pi V/\omega$$

where V is the wave velocity.

WAVELENGTH OF YAW. A term used in rocket aerodynamics referring to the fact that when a rocket yaws its period of oscillation is inversely proportional to the velocity. As a result, a rocket traverses the same distance while performing an oscillation, regardless of velocity. This distance for a complete cycle of oscillation, is called the wavelength of yaw. It is given by:

$$\sigma = 2\pi \sqrt{\frac{Mk^2\rho}{K_M d^3}}$$

Where σ is the wavelength of yaw, M is the mass of the rocket, k is the radius of gyration (about a transverse axis through the center of gravity), ρ is the air density, K_M is the coefficient of moment, and d is the diameter of the rocket.

WAVEMETER. An instrument used to indicate or record wavelength. It actually measures frequency, but reads in wave length. Wavemeters may operate on the heterodyne or beat principle, or they may be of the absorption type which employs the principle of resonance.

WDD. The Western Development Division. Air Research and Development Command; Los Angeles, California [New designation for WDD is BMD (Ballistic Missiles Division)].

WEAPON EFFECTIVENESS. The degree to which a weapon system can perform its mission with minimum drain on national resources.

WEAPON EVALUATION (ANALYSIS). The science of determining weapon effectiveness through techniques of operations research.

WEAPON SYSTEM. A group of tactical devices which together perform a mission, i.e., detect a target, identify it as friend or foe, deliver a payload upon it, and assess the resulting damage. The complete Weapon System includes the equipment, skills, techniques and personnel required for providing the desired role or mission in the operational environment.

WEAPON SYSTEM PROJECT OFFICE (WSPO) (Of the USAF Air Material Command). A central point for management control of one or more weapon system programs. It is established to achieve proper phasing of actions in development, procurement, maintenance, and supply, thereby insur-

ing timely delivery and support of weapon systems. An important function of this office is that of providing a central contact point for industry and Air Force relations.

WEAPON SYSTEM SPECIFICATION. A top specification developed in accordance with military requirements which outlines the design criteria and performance requirements for the weapon, the support equipment, facilities and manpower.

WEAROUT FAILURE. Failure modes.

WEARY WILLIE. A project which used combat-useless B-17's or B-24's as radio-controlled drones. They were filled with explosives, and flown into point targets by accompanying aircraft. The plan called for a pilot to take the Weary Willie off the ground, set its automatic pilot for some pre-determined course and then parachute out, allowing the controls to be taken over by the "mother" ship.

WEATHERCOCK (STABILITY). (1) An aerodynamic characteristic of a body which points it into the relative wind. (2) The partial derivatives of yawing and pitching moments with respect to angles of attack in yaw and pitch establish the stability characteristics. (See *stability derivatives*.)

WEB (THICKNESS). In unrestricted-burning solid-propellant rocket grains, the minimum distance which can burn through, as measured perpendicular to the burning surface.

WEBER NUMBER. In fluid mechanics, a dimensionless product:

$$W = \frac{\rho v^2 L}{\sigma}$$

Where W is the Weber number, ρ is the mass density, v is the velocity, L is the length, and σ is the surface tension.

WEIGHT. The force with which a body is attracted toward the earth; the product of the mass of a body and the acceleration attributable to gravity. The force of 980 dynes is the weight of one gram at the place where the acceleration of gravity equals 980 cm/sec². The value of the acceleration due to gravity increases slightly from equator to pole so that the weight of a body varies according to its

geographical location. The mass of a body, however, is constant.

In view of the difficulty, under most circumstances, of determining mass directly, masses are commonly determined in chemical operations by comparison of the weight of the unknown mass with the weight of known masses, a process called weighing, which involves, in very accurate work, certain corrections or methods to avoid the necessity for those corrections. (See *weighing methods*.)

Although the above definition is satisfactory in most cases, some ambiguities in the meaning of the term "weight" may arise, and various authors differ in its use. For example, the weight of a solid object submerged in a fluid less dense than itself may be said to be either the same as that of the body in air or equal to the weight in air less the **buoyancy**. Some writers speak of the latter as the apparent weight. An even finer distinction arises when we ask whether the weight of an object is the gravitational force on it, or whether it is that force added vectorially to the **centrifugal force** resulting from the earth's rotation. Because of the wide variety of usage, one must often judge from context as to the exact meaning of the term in doubtful instances.

WEIGHT BOGEY. A system or group weight established as a target at the start of a design. (It is usually fixed by the weight group and is periodically adjusted as a program progresses.) It is also termed Target Weight.

WEIGHT FLOW CORRECTION FACTOR. The ratio of actual to theoretical weight flow through a rocket motor, not counting injected coolant fluid.

WEIGHT, G. Accelerometer; g-weight.

WEIGHT LOADING FACTOR. In rocket aerodynamics, a term which approximates the ratio of thrust and drag. It is given by:

$$\mu = \frac{W_o}{A}$$

Where μ is the weight loading factor, W_o is the takeoff weight of the missile, and A is the reference (drag) area. A high value of μ means that only a small fraction of the thrust need be diverted from lifting the missile to overcome drag, and better performance is to be expected.

WEIGHTLESSNESS. The result of zero gravity. It is experienced at any point where no acceleration exists, as in a satellite. The effect of weightlessness on test animals and humans has been tested for a number of years. The Soviet dog experiment in Sputnik II showed that a test animal could survive for a period long enough to go to the Moon and return in a weightless condition. Analysis of the pulse, blood pressure, and respiration of *Laika*, the Sputnik II passenger, showed no harm to the dog because of the impondability, according to Soviet reports. Humans subjected to weightless conditions for 10-20 seconds in aircraft intentionally flown on a parabolic path have felt variously. Some persons are exhilarated, others made nauseous. Drinking is difficult under conditions of lack of appression since fluids are likely to float out of open containers and break apart into droplets. Body motions are hard to control since each movement must be consciously braked.

WEIGHTS REPORT. A report commonly used in missile design which includes detail weights (estimated, calculated or actual weights), mass distribution, moments, location of center of gravity of each component, weight distribution by station for inertial calculations, weight and center of gravity variation as function of time and/or velocity or Mach number for boost and flight phases. Usually three weight report are submitted: *Estimated*, *Calculated*, and *Actual*.

WESCOTT. A British (British Royal Aircraft Establishment), 50,000-pound thrust rocket. It has a spherical combustion chamber made up of 32 leaves of double wall stainless steel for regenerative cooling. It burns kerosene with liquid oxygen at 500 psi chamber pressure. Kerosene propellant at 800 psi is used to maintain this pressure.

WET WEIGHT. In propulsion, a term referring to the total weight of a propulsion unit, including the necessary plumbing and the residual propellants within the plumbing (e.g., in the regenerative cooling lines, manifolds and within the motor walls, in the pumps, etc.). It is opposed to the dry weight, which is the weight of the propulsion unit with plumbing, but less circulating fuels weight.

WHITE DWARFS. In the article on **giant and dwarf stars** it was shown that more than 99% of the observed stars may be classified either as super giants, giants, or main sequence stars. A few stars do not fit into this general scheme at all and form a unique and little understood class known as the white dwarfs. The first star of this class to be discovered was the companion star to Sirius. The **orbit** of the pair has been computed, and from it the mass of the companion was computed and found to be about the same as that of the sun. Its **absolute magnitude** was known and the luminosity found to be about 1/360 that of the sun. On the ordinary giant and dwarf hypothesis such a star should be in the dwarf M-type **spectral class** having low brightness per unit area. However, when its spectral class was finally determined it was found to be of class F and hence hotter than the sun and brighter per unit area. From the brightness per unit area and the intrinsic brightness, the diameter can be computed, and it is found to be about 30,000 miles, or of planetary dimensions. This means that we have an object of stellar mass and planetary dimensions, and an unbelievably great density, of the order of magnitude of 30,000 times the density of water. At such a density a cu. ft. of this stellar material would weigh 935 tons.

This star is one of the general class known as white dwarfs, all with spectral classes between A and F. The total number of such stars is not known, for they are all apparently very faint and cannot be detected as white dwarfs except by spectrographic analysis, which is difficult for faint objects. Furthermore, their intrinsic brightness is so small that only the closer ones would be observed at all (the few known at present are all within 15 light years of the sun).

The problem of the internal constitution of objects of such great density is as yet far from completely solved. The best hypothesis is that the material consists of atomic nuclei stripped of **electrons** and tightly packed together by gravitational compression.

WHITE NOISE. (1) Random noise, such as **shot noise** and **thermal noise** which has a constant energy per unit bandwidth that is independent of the central frequency of the band. The name is drawn from the analogous definition of white light. (2) The electrical disturbance caused by the random movement

of free electrons in a conductor or semi-conductor. Since the electrical energy in this type of noise is evenly distributed throughout the entire frequency spectrum, it lends itself to use in testing frequency response of amplifiers, speakers, etc.

WILSON CLOUD. A misty cloud of short duration, caused by the condensation of water vapor in the air due to the drop in temperature that accompanies the passage of the refraction in a shock wave.

WHISKER. (1) The fine, sharpened electrode forced into contact with the semiconductor material in a **semiconductor diode** or point-contact transistor. (2) Certain small crystals possessing great **shear** strength. For example, it has been shown that a very small crystal of tin (10^{-4} cm in diameter) can tolerate extremely large strains in bending without plastic deformation. This large shear strength, approaching the classical limit, is due to the absence of dislocations.

WHITE SANDS PROVING GROUND. The U.S. Army Ordnance missile range located approximately 28 miles from Las Cruces, New Mexico, north of the Fort Bliss, Texas military reservation. The range was established in 1944 and opened July 9, 1945. In 1956, the available range area was 125 x 45 miles. The White Sands range was originally developed for the Jet Propulsion Laboratory experiments.

WILD T-2 THEODOLITE. A precise surveying instrument. It can measure angles directly to one second. All scales are enclosed and read through a 100-power microscope. It does not measure vertical angles but reads "zenith distance," i.e., when pointed vertically the telescope reads 0° and when pointed horizontally it reads 90° . This equipment is available in the U.S. Army in all situations requiring second-order survey accuracies.

WIND, CROSS. Cross wind.

WIND, CYCLOSTROPHIC. Cyclostrophic wind.

WIND, GEOSTROPHIC. Geostrophic wind.

WIND, KATABATIC. Katabatic wind.

WIND PROFILE. A graphical distribution of the steady wind speed over a large altitude range.

WIND, RELATIVE. The velocity and direction of the air with reference to a body moving in it. It is usually determined from measurements made at such a distance from the body that the disturbing effect of the body upon the air is negligible.

WIND ROSE. Any diagram showing features of wind direction and velocity in the form of a hub, with spokes of a wheel representing direction or velocity values or both. The most common wind rose is one in which the length of the spokes of the wheel extending into the cardinal directions represents the frequency of winds from that direction.

WIND SCALE. Beaufort wind scale.

WIND SHEAR. The average wind gradient; the difference in the wind velocity at two altitudes divided by the altitude increment. The units are ft per sec/1000 ft.

WIND TUNNEL. A test device for producing a controlled wind or air stream, in which objects can be placed for investigating the air flow about them and the aerodynamic forces exerted on them.

WIND VANE. An arrow with considerable tail surface. Air flowing past the tail surface keeps the arrow pointed in the direction from which the wind is coming. The vane is usually mounted some 20-30 ft above the ground or water level.

WIND, VEERING. Veering wind.

WINDS. (See also **circulation of the atmosphere**.) Winds can be divided into four categories:

(1) Gradient winds blow in accordance with the existing pressure gradient, centrifugal force and **Coriolis force**.

a. Cyclonic winds blow counterclockwise about regions of relatively low pressure in the northern hemisphere and clockwise in the southern hemisphere.

b. Anticyclonic winds blow clockwise about regions of relatively high pressure in the northern hemisphere and counterclockwise in the southern hemisphere.

(2) Geostrophic winds blow in accordance

with the pressure gradient, but only where the pressure gradient is balanced by the Coriolis force. They are, therefore, winds which blow in straight or nearly straight lines over the earth. Geostrophic winds are not possible at the equator because there is no Coriolis force present.

(3) Cyclostrophic winds blow cyclonically in both hemispheres in wind systems where the pressure gradient is balanced by centrifugal force in the absence of the Coriolis force. Cyclostrophic winds occur near the equator as hurricanes and other local less intense vortices.

(4) Antitriptic winds are small-scale, short duration winds which blow, in general, along the pressure gradient. Land and sea breezes are of this type.

In general, winds are mainly gradient winds. Many strictly local winds blow over relatively small regions. Most of these occur where there is sharp contrast in surface temperature over a relatively small distance or where terrain is highly irregular. Sea breezes blow from cool water to heated land during the heat of day. Land breezes blow from cooled land to warmer water during the cool of the night. Valley breezes blow upslope in valley-hill terrain during sunny days, and mountain breezes blow downhill in a reverse manner during darkness. Mountain breezes often become very strong and extremely variable as a result of large-scale eddies and Venturi effects in mountain passes. (See also **Beaufort wind scale**.)

WINDOW. Strips of frequency-cut metal foil, wire or bars which may be dropped from aircraft or missiles or expelled from shells or rockets as a radar countermeasure. (See **reflector**, **confusion**.)

WINDOW ROCKET. A rocket designed to carry window.

WING. An airfoil used principally for lift; therefore usually the largest airfoil found on an aerodynamic missile.

WING CONTROL. A method of aerodynamically controlling a missile, wherein the control surfaces are located near the center of the body and become the main lifting surface; tail surfaces are mounted at the rear of the missile mainly for stabilizing purposes.

WING-CONTROL-DURING-BOOST. A technique used for boost phase attitude stabilization, wherein winged missiles are controlled as a **canard** configuration. After the booster rocket is jettisoned or staged the wings may be used for midcourse control.

WING LOADING. For a missile in level flight, the ratio of load on its wing to the wing area.

WING PLANFORM. The outline of a wing when viewed perpendicular to its surface.

WINTERIZATION. Preparation of material to permit storage and operation in frigid regions by such means as insulation against cold, addition of heating elements, changes in lubricants, and changes in dimensional clearances of parts to a point where operation at extremely low temperature is reasonably efficient.

WIZARD. A U.S. Air Force liquid propellant rocket, manufactured by RCA and Convair, now in the research stage, designed as an anti-ICBM device. (See **missile**, **guided**.)

WLANC DATA BOX. An instrument produced by the Watson Laboratories Air Materiel Command for the photographic recording of radar data. The instrument photographs a special dial presentation panel set up to display complete data for the camera in a convenient arrangement.

WOBBULATION. (1) Similar to **gyroscope** mutations; a source of drift in single axis gyros. (2) Variation of a steady-state frequency for test purposes.

WOBBULATOR. A device, usually mechanical, used to frequency-modulate an **oscillator** for test purposes. A small trimmer capacitor rotating at constant velocity across the frequency-determining network of the oscillator is an example.

WOLFRAM. **Tungsten.**

WOOFER. A loudspeaker device to accentuate base tones. It is a low-frequency loudspeaker.

WOOFUS. The popular name for the U.S. Navy's 7.2 inch rocket developed during World War II. (See **rocket**, **7.2 inch**.)

WOOMERA. A 1500-mile overland rocket proving ground, located in northwest Australia. It is used for testing long range missiles developed within the British Commonwealth.

WORD. In digital computer applications, an instruction, a number or an arbitrarily coded quantity.

WORKING LOAD. Load, working.

WOW. Speed variation in reproduced sound, i.e., a low-frequency flutter.

WPAFB. Wright-Patterson Air Force Base; Dayton, Ohio.

WR. War Reserve.

WS. Weapon System. SM-62, Northrop Snark; WS-104A, SM-64, North American Navaho; WS-107A-1, SM-65, Convair Atlas; WS-107A-2, SM-68, Martin Titan; WS-110A, North American chemical bomber program; WS-117L, Lockheed, Pied Piper; WS-123A, SM-73, Fairchild Goose; WS-126A, BDM for B-52; WS-131B, GAM-77, Hound Dog; WS-132A, BDM for WS-110A; WS-133A, SM-80, Minuteman; WS-200A, IM-99, Boeing Bomarc; WS-309A, TM-76B, Martin Mace; WS-315A, SM-75, Douglas Thor.

WSEG. Weapons Systems Evaluation Group.

WSM. Weapons Systems Manager.

WSPG. White Sands Proving Ground; Las Cruces, New Mexico.

WSPO. Weapon System Project Office.

WSSM. Weapon System Supply Manager.

WWV. The call signs of the U.S. National

Bureau of Standards (Department of Commerce) radio transmitter at Beltsville, Maryland. This station broadcasts continuously, transmitting time references all over the world. This station and a twin in Hawaii (WWVH), both transmit on 2.5, 5, 10, 15, 20 and 25 mc/s sending out a beat every second (400 cps tone, voice and other announcements as indicated below are also transmitted). This beat is accurate to 100-millionth of a second. WWV is synchronized with the Naval Observatory, which determines time astronomically. WWV uses a quartz crystal in an air-conditioned well 22 feet below floor level, which vibrates at a 100,000 cps. During each hour it broadcasts 12 voice announcements of eastern standard time, 12 Morse code signals of Universal (Greenwich, England), time, 6 audible tones of 600 cps, 5 audible tones of 440 cps, 2 radio-propagation forecasts for the next 6-hour period, 2 IGY reports (sun's activity, magnetic storms, etc.). Every hour, except for a 4-minute silence period for the measurement of atmospheric noise, each second is marked off by ticks. Since the 59th tick is omitted and the 60th tick is doubled to mark the minute, it is possible to identify seconds and minutes, but the eastern standard time announcement each five minutes is required to check civil time. The 440 cps tone is the standard musical pitch ("A" above middle "C"), and is furnished to check tuning forks (piano tuners and organ manufacturers use this). The 600 cps tone is used for electronic multiplication and division for frequency reference. The time given in code uses the standard Morse characters as follows:

1 . - - - -	6 -
2 . . - - -	7 - - . . .
3 . . . - -	8 - - - . .
4 -	9 - - - - .
5	0 - - - - -

X

X. (1) Reactance (X), capacitive reactance (X_c), inductive reactance (X_L), specific acoustic reactance (X). (2) Rectangular coordinates (x,y,z). (3) Mole fraction in liquid (X). (4) Mole ratio in liquid (x). (5) Distance above datum plane in direction of flow (x). (6) Longitudinal displacement (x). (7) Experimental (X). (8) Longitudinal axis (X). (9) Frequency within range 5,200-11,000 mc/s (X).

X TIME. In the most common usage, X -time is used for timing events prior to missile liftoff, and $X+$ time is used for timing events after missile liftoff. However, all time before the missile launching may be designated as X -time, e.g., $X - 60$ (pronounced: "X minus six zero"), and all time after take-off of the vehicle is designated as T -time, e.g., $T + 180$ (pronounced: T plus one hundred eighty).

X-1, X-2, X-3, X-4, X-5, X-6, & X-7. A series of German World War II guided missiles developed by the Ruhrstahl Company. These were mostly subsonic, with two of the series being supersonic. They were designed as both air and ground weapons, and were controlled by radio or trail wires. $X-1$ was called the Ruhrstahl, and was intended as an air-to-ground weapon, having no propulsion. It weighed 1.4 tons, was 3.26 meters long, and had an effective region of 5 x 8 kilometers. It was also called "Fritz-X" and the "SD-1400." The $X-2$ and $X-3$ were further improvements of the $X-1$ guided bomb and were also gravity-powered. $X-4$ was a subsonic, wire-controlled, air-to-air missile weighing approximately 60 kg. It had a liquid rocket motor and three midwings of a peculiar curving taper. $X-5$ and $X-6$ were improvements to $X-1$ and were supersonic. $X-7$ was a small antitank missile weighing 9 kilograms. It was both fin and spin stabilized, the tail fins being offset for spin.

X-2. An experimental rocket ship developed by Bell Aircraft similar to the earlier $X-1A$. It had a swept-wing of stainless steel, and a

K-monel fuselage in order to withstand the high frictional temperatures encountered. It had an air conditioned pressurized pilot's compartment which could also be heated for extreme altitudes or cooled for supersonic speeds. The power plant was a Curtis XLR-25 rocket motor with a hand throttle controlling thrust. Total thrust available was 15,000 pounds. The insulated cockpit was jettisonable, and could be lowered by ribbon parachute to a point where the pilot could bail out. The windshield was made of a high temperature glass, resistant to 1000°F. It was air-launched from a B-50 mother ship. It was flown by Captain Kincheloe to 23 miles altitude.

X-3. A Douglas Aircraft Company experimental supersonic aircraft which first flew in 1952. It was designed for operation at Mach 3. The aircraft was 66 feet 9 inches long, with a span of 22 feet 8 inches. Power was by two Westinghouse J34-17 turbojets with afterburners giving a total thrust of 9,000 pounds.

X-4. A German World War II missile designed for air-to-air combat. As it flew the missile trailed behind it a twisted pair of wires, 4 miles long. Commands were sent over these wires. It was capable of a top speed of 620 miles per hour. It rotated at 60 rpm for stability. It carried 4 swept-back wooden wings of about 3 feet span and weighed about 100 lbs. Its normal carrier was the Focke-Wulf Fw 190 fighter. Later models were planned for radio command guidance. The missile was never used in combat.

X-7. The Lockheed Missile Systems Div. ramjet test vehicle built for the U.S. Air Research and Development Command. It had a cigar-shaped body, with a needle nose having a body-centered mid-wing with square tips, and tapered leading and trailing edges. It had a single vertical stabilizing fin at the tail, with horizontal stabilizing surfaces similar in shape to the wings. The ramjet motor is made by Marquardt Aircraft. It was

launched at altitude from a B-29, and rocket-boosted to speed at which ramjet takes over to accelerate to final speed. Recovery was by parachute followed by impact crushing of the needle nose. The vehicle was tested at the Holloman Air Development Center. It is used as basis for U.S. Army Kingfisher drone. (See **missile, guided**.)

X-10. A test vehicle developed by the North American Aviation Company for preparatory investigations for the **Navaho** missile. It was powered by two J-40 turbojets and was equipped with retractable landing gear for post-flight recovery. It was successfully flown at both Edwards Air Force Base, California and Cape Canaveral, Florida. The vehicle attained speeds of approximately Mach 2 and was consistently recovered with a high re-use factor.

X-15. The North American Aviation near-orbital manned rocket study development. First air-launched flights are to be made during 1959, with full performance flights expected in 1960. Its design calls for 50 miles operational altitude. It is a joint U.S.A.F.-Navy-NASA project.

X-17. The Lockheed Aircraft Missile Systems Div. re-entry test missile used by the U.S. Air Force for investigations for their IRBM and ICBM programs. It is a three-stage solid-propellant carrier intended to be boosted upward, and to fire its second and third stages while descending earthward. This gives the final stage Mach numbers approximating those to be experienced by the longer-range missiles. The firing was first conducted by Lockheed at Cape Canaveral, Florida during the period 1955-1957. The first stage was a **Sergeant** solid propellant rocket, the second, three **Recruit** rockets and the third stage a single **Recruit**. More recently the X-17 has been used to explore **Polaris** problems. The X-17 weighs more than 12,000 lbs., and has reached speeds of 9000 m.p.h. Its length is 40 ft., and its payload is 75 lb. of instruments.

X-405. The General Electric Company's 27,000-pound thrust, liquid rocket engine. It had a burning time of 150 seconds, and is used in **Vanguard** first stage.

X BAND. A radio frequency band of 5,200 to 11,000 megacycles with wave lengths ranging from 5.77 to 2.73 centimeters respectively.

XBG-1. A World War II air-to-surface missile designed for launching as a glider. It was towed behind a mother aircraft and then cut loose short of the target. Radio control carried the glider on into the target. The missile was a full-size troop-carrying glider. It was never used tactically. The **XBG-2** was an improved version.

XBQ-1. A remote-controlled aircraft missile intended to be used as a drone bomber. The Fleetwing Aircraft Company made these high-wing monoplanes during World War II. They were powered by two reciprocating engines. Control equipment consisted of the radio command link and a television link. The weapon was never used tactically. It was designed to carry a 1-ton bomb load.

XBQ-2A. A remote controlled aircraft similar to the **XBQ-1** with more powerful motors. It was discontinued as a program during development.

XBQ-3. A World War II pilotless aircraft developed by the Fairchild Engine and Airplane Corporation. It could carry a 2-ton bomb load and was powered by two Ranger gasoline engines. Radio and television were used for control. This missile was discontinued before completion.

XBQ-4. A World War II pilotless aircraft project. These planes were popularly called **Weary Willies**. The plan was to use B-17 and B-24 aircraft no longer fit for regular service as drone bombers. Such aircraft were actually used during combat against the submarine pens on the coast of France. Results were not successful.

Xe. Xenon.

XENON. Gaseous element, one of the rare gases of the atmosphere (present to the extent of somewhat less than 1 part per million in air). Symbol Xe. Atomic number 54.

XGAM. The U.S. Air Force designation for experimental guided air missiles (air-to-air). This designation would be followed by the individual number pertaining to that particular project, e.g., **XGAM-17**.

XKDB-1. A U.S. Navy target drone made by the Beech Aircraft Co. It was a conventional high-wing monoplane with a V-tail.

XKD4R-1. A U.S. Navy target **drone** built by the Radioplane Corporation.

XKDT-1. A U.S. Navy **drone** produced by Temco Aircraft.

XLR-25-CW-1. A U.S. experimental liquid-propellant rocket motor of 15,000 pounds thrust. It used a turbine pump feed and had two combustion chambers. It was developed by the General Electric Company.

XM-3. Hawk.

XM-47. Little John.

XQ-4 AND XQ-5. Target **drones** developed by Radioplane Corporation.

X-RAYS. Energetic high-frequency electromagnetic radiation produced in a variety of ways. X-rays are produced, (1) when electrons, accelerated in a vacuum, strike a target and lose kinetic energy in passing through the strong electric fields surrounding the target nuclei, thus giving rise to *bremsstrahlung* and resulting in a continuous x-ray spectrum. The fact that x-rays can be produced in still other ways is evident from the recent discovery of a region of intense x-ray activity in the earth's upper atmosphere; (2) by the transitions of atoms from higher energy states to K, L, ... energy states, thus giving rise to characteristic x-rays. The term x-rays is not used to refer to the characteristic radiation from an element of atomic number Z less than 10, since the wavelengths of such radiation exceed those in the x-ray range. However, every element has its characteristic x-ray spectrum, when used as a target, although according to the Duane and Hunt law the radia-

tion also depends on the accelerating voltage.

There are three principal means of detecting x-rays: the fluorescent effect, the photographic effect, and the ionizing effect. The only method at first available for distinguishing radiations of different wavelength was to measure their penetration or their **absorption coefficient** in various substances. The discovery of the x-ray **diffraction** or grating effect of crystals, by von Laue, Friedrich, and Knipping, in 1912, made it possible to analyze the rays and measure their wavelengths very much as light is studied with the spectroscope. When x-rays of given wavelength are incident upon a crystal turned in various directions, the layers of atoms, at certain angles of incidence, reflect wave trains in phase with each other which, if caught on a photographic plate, produce a "Laue pattern." While the matter is not as simple as in the case of light incident on a **diffraction grating**, it is nevertheless possible to interpret such patterns in somewhat the same way as a line spectrum, and to deduce the wavelength from it. A unit convenient for expressing x-ray wavelengths is the "x-unit," which is 10^{-11} cm. or 0.001 angstrom.

Recently, a band of intense x-radiation has been found in the upper atmosphere. This discovery, which was evidenced by saturation of the cosmic ray instruments in the Explorer satellites, occurred at an altitude of about 600 miles above the earth. The x-rays are believed to be produced by corpuscular radiation from the sun (possible electrons and protons) which are deflected by the earth's magnetic field into an orbit that is roughly parallel to the surface of the earth.

XYLOPHONE. Rocket, 4.5 inch.

Y

Y. (1) Admittance (Y), admittance with plate load, or grid or input (y_g), admittance, output (y_o). (2) Rectangular coordinates (x, y, z). (3) Yttrium (Y). (4) Mole fraction in vapor (y). (5) Mole ratio in vapor (Y). (6) Depth or height (y). (7) Height of object (y). (8) Height of image (y'). (9) Altitude (y). (10) Transverse acoustical displacement (y). (11) Young modulus of elasticity (Y). (12) Super compressibility factor (y). (13) Lateral axis (Y). (14) Yaw force (Y). (15) Designation of prototype model of missile (Y).

YAW. In aerodynamics, an angular displacement about an axis parallel to the normal axis of the vehicle. Yawing causes the vehicle to turn crosswise in flight causing increased air resistance and, if it proceeds too far, a disturbance of the flight path. The angle of yaw is the acute angle between the direction of the relative wind and the plane of symmetry of the airframe. The angle is positive when the yaw is to the right. Yaw consists of a motion about an axis through the center of gravity of the airframe in a direction perpendicular to the longitudinal axis. Yaw is controllable in several ways. In small rockets it is controlled by the gyroscopic effect of a fast spinning motion, or by affixing of tail fins (in the same aerodynamic process used by an arrow). Tail fins are of course of no value in space and spin-stabilization is not feasible where a stable reference platform must be maintained for guidance. For large rockets, some form of spatial control using thrust direction control must be used in space. The several aerodynamic terms associated with yaw are: yaw angle, yaw angular velocity, yaw linear velocity, yawing moments coefficient.

Yb. Ytterbium.

Y-CONNECTION. In electricity, a connection in the shape of a "Y". It is sometimes called a star connection.

YAGI. An antenna array used for television and other very high frequency use.

YEAR. Time.

YIELD. The energy released by detonation of a nuclear weapon, usually measured in kilotons or megatons of equivalent TNT. The atomic bomb dropped on Hiroshima had a 20 kiloton (KT) yield.

YIELD POINT. The load per unit of original cross section at which, e.g., in soft steel, a marked increase in deformation occurs without increase in load. In other steels and in nonferrous metals, yield point is the stress corresponding to some definite and arbitrary total deformation, permanent deformation of slope of the stress deformation curve; this is more properly termed the **yield strength**.

YIELD STRENGTH. Stress corresponding to some fixed permanent deformation such as 0.1% or 0.2% offset from the modulus slope.

Y_k . Propellant Loading Ratio.

YOUNG'S MODULUS. An expression of the elasticity of a material. It is stated in lb/in² and is valid only within the **elastic limit** of the material.

YTTERBIUM. Rare earth metallic element. Symbol Yb. Atomic number 70.

YTTRIUM. Rare metallic element. Symbol Y or Yt. Atomic number 39.

Z

Z. (1) Atomic number (Z). (2) Gram-equivalent weight (Z). (3) Molecular collision frequency (Z). (4) Distance above datum plane (z). (5) Modulus of section (Z). (6) Impedance or acoustic impedance (Z), specific acoustic impedance (z). (7) Rectangular coordinates (x, y, z). (8) Radius of circle of least confusion (Z). (9) Complex variable (z). (10) Super compressibility factor (z). (11) Normal axis (Z).

Z.I. Zone of Interior.

Z-BATTERY ROCKET. A British World War II surface-to-air solid propellant (cordite) rocket missile fired for anti-aircraft purposes in salvos of 48. The missile weighed 56 pounds, with a 20 pound payload (9.5 pounds of this TNT). Length was 6 feet with a 4 inch diameter. It was fin-stabilized and good to an altitude of 20,000 feet.

Z-GUN. The launcher used with an anti-aircraft rocket developed by the British during World War II. It was a gun-type carriage capable of rotation and elevation. Each Z-gun held two rockets. These were served by a two-man crew. Azimuth and elevation were set on the gun by voice commands over a loudspeaker.

Z-TIME. Greenwich Mean Time. This time is used for communications, navigation and other uses where a correlation of time is required. Z-time is obtained by adding five hours to Eastern Standard Time.

ZEBRA TIME. Greenwich Mean Time. (See **Z-time**.)

ZEEMAN EFFECT. An effect of a moderately intense magnetic field upon the structure of the spectrum lines of a gas when subjected to its influence. The phenomenon, sought unsuccessfully by Faraday and finally observed by Zeeman in 1896, consists in the splitting up of each line into two or more components. In the simpler cases, when the source is viewed at right angles to the field, there are three

components, of which the middle one has the same frequency as the unmodified line. This component is plane-polarized to vibrate parallel with the field, while the two side components vibrate at right angles to the field. When the source is viewed in the direction of the field, there are only two components, displaced in opposite directions, and circularly polarized in opposite senses. (See **polarized light**.) These phenomena constitute the so-called "normal" Zeeman effect.

With most lines, however, the number of components is greater, in some cases reaching twelve or fifteen, the "anomalous" Zeeman effect. They are symmetrically arranged and symmetrically polarized. The displacements, as in the simpler case, are proportional to the magnetic field intensity H , and are always expressible, in wave numbers, as rational multiples of the displacement in the normal effect, which is $4.67 \times 10^{-5}H$ (reciprocal centimeter), a quantity known as the "Lorentz unit." The anomalous Zeeman effect is explained by assuming that the magnitude of the term splittings for a given field strength is not the same for all terms, but differs according to the values of the quantum numbers L and J .

ZENER CURRENT. The current through an insulator in a very intense electric field, sufficient to excite an electron directly from the valence band to the conduction band.

ZENER VOLTAGE. (1) The field required to excite the Zener current, of the order of 1 volt per unit cell or 10^7 volts/cm. (2) The voltage associated with that portion of the reverse volt-ampere characteristic of a semiconductor wherein the voltage remains substantially constant over an appreciable range of current values.

ZENITH. The point on the celestial sphere directly overhead is the observer's zenith. The astronomical zenith is defined as the point where the plumb line extended up from the surface of the earth will intersect the celestial

sphere. Owing to the fact that the plumb line may be affected by local gravitational effects, such as large mountains in the vicinity, the geographical zenith is the point where a line perpendicular to the surface of a smooth earth would intersect the celestial sphere. The angular distance between the astronomical and geographical zenith is the station error of the point on the surface of the earth. Because of the fact that the earth is an oblate spheroid rather than a perfect sphere, neither the plumb line nor a perpendicular to the surface of the earth will pass through the geometrical center of the earth unless the observer is either at one of the poles or is on the **equator**. The geocentric zenith is defined as the point where a line extended from the center of the earth through the observer will intersect the celestial sphere. The angular distance between the astronomical and geocentric zenith is the reduction of **latitude** for the observer.

ZENITH DISTANCE. The angular distance of a celestial body from the zenith, measured through 90° along a vertical circle passing through the body, and equal to 90° minus the altitude of the body.

The zenith distance is sometimes expressed in nautical miles between the observer and the subpoint of the celestial body. When zenith distance is expressed in degrees, it is also called the "co-altitude."

ZENITH-NADIR AXIS. A line connecting the **zenith** and **nadir** of an observer.

ZERO BEAT. In electronics, a system of comparing one frequency with another by combining the two and noting the resultant **beats** (i.e., reinforcements and cancellations of wave amplitude due to differences in phase). As the two frequencies being compared grow closer to each other, the beats diminish until there is a zero difference, and thus zero beat. In the case of audio frequencies, there is silence at zero beat. This scheme of producing an audible sound from the difference frequency permits accurate adjustment of a variable frequency to a reference frequency. When there is a zero beat the two are equal. The method is used for tuning resonant circuits.

ZERO GRAVITY. A condition existent when the centripetal gravitational attraction of the earth or other spatial body is nullified by inertial (centrifugal) forces

ZERO-LENGTH LAUNCHING. A technique in which first motion of the missile removes it from the launcher. A zero-length launcher orients the missile initially, but has no significant effect on the missile flight path.

ZERO-LIFT DRAG. The total drag upon a missile experiencing no lift. The integral of all axial components of forces acting on the outside of a body with attached flow conditions at the lip of the inlet or of a cylindrical body (which is the usual design for the main body section of a guided missile). The forces are caused by viscous phenomena (skin friction) only.

ZERO LIFT TRAJECTORY. A trajectory in which the control system acts to maintain a condition of no aerodynamic lift on the missile.

ZERO POINT ENERGY. The kinetic energy remaining in a substance at the absolute zero point of temperature. According to quantum mechanics, a simple harmonic oscillator does not have a stationary state of zero kinetic energy. The ground state has still one half quantum, $h\nu$, of energy, and the motion corresponding thereto. This agrees with the **uncertainty principle**, which does not permit the oscillator particle to be absolutely at rest exactly at the origin. In solids the zero-point energy is distributed in the normal modes of lattice vibration, and may be an appreciable term in the binding energy of the crystal, especially in hydrogen, helium, rare gases, etc. The motion may be observed in x-ray diffraction, but does not contribute to electronic resistivity. (See also **oscillator**, **harmonic**.)

ZERO TIME. In missile proving ground usage, that time for a given operation from which all elapsed time is measured for instrumentation reference and data reduction correlation. It does not necessarily coincide with vehicle first motion. At some ranges, range timing is re-cycled to zero at vehicle first motion to provide a more convenient correlation. Where heavier schedules of launchings exist, timing cannot be re-cycled for every user. Zero time is the instant when the missile firing preparation reaches the point where the ignition or takeoff sequence begins. Actual first motion may be anywhere from a fraction of a second to many seconds later. (See **timing**, **T-time**, and **X-time**.)

ZINC. Metallic element. Symbol Zn. Atomic number 30.

ZIP FUEL. The popular name (and also the project name) for the exotic non-hydrocarbon type fuels now being developed. The alkyl boranes and various hydrides of light metals are examples. The composition of many of them has not been revealed. (See **high energy fuel**.)

ZIRCONIUM. Metallic element. Symbol Zr. Atomic number 40.

Zn. Zinc.

ZODIAC. The zodiac is a belt on the celestial sphere which extends for an angular distance of 9° either side of the **ecliptic**. This belt is divided into 12 sections, each 30° long, which are known as the signs of the zodiac. These signs indicate the position of the sun for each month in the year and are named for the **zodiacal constellations** which occupied the signs about 2000 years ago. Due to **precession** the sign of **Aries** has moved back into the constellation of **Pisces**, so that the signs and constellation names no longer agree.

Since the **planets** all lie relatively close to the ecliptic their paths along the celestial sphere will lie in the zodiac. It is a common practice with makers of almanacs to indicate the positions of the planets by the sign of the zodiac in which they are to be found.

ZODIACAL LIGHT. The zodiacal light is a faint glow which appears extending along the **ecliptic** or **zodiac** from the vicinity of the sun. It may best be observed in the western sky in the spring after the sunset twilight has completely disappeared or in the eastern sky in the fall just before the morning twilight appears. It is so faint that it is completely masked by moonlight. The zodiacal light decreases in intensity with distance from the sun, but on very dark and clear nights it has been followed completely around the ecliptic. In fact, the work of van Rhijn at the Mount

Wilson Observatory indicates that the illumination is not confined to the ecliptic, but presumably covers the entire sky, being responsible for about 60% of the total skylight on a moonless night. There is a slightly increased illumination of the zodiacal light on the ecliptic directly opposite the sun known as the *gegenstein*.

Photographic observations of the spectrum of the zodiacal light indicate that it is composed of reflected sunlight. The amount of material necessary to produce the intensity of the zodiacal light is amazingly small. Calculation indicates that the zodiacal light could be accounted for, if, inside the orbit of the earth, there were particles 1 mm. in diameter of the reflecting power of the moon, and each one 5 miles from its neighbors.

Observational studies indicate that the material producing the zodiacal light is located in a lens-shaped volume of space centered on the sun and extending well out beyond the **orbit** of the earth. Each individual particle, unless small enough to be held away from the sun by **radiation pressure**, must be moving about the sun in its individual orbit. The intensification of the reflected light at the point directly opposite the sun might be explained either by a concentration of the reflecting particles in this region, or by the fact that directly opposite the sun the particles would be in full phase.

ZONE BOX. An electrical device which generates an exact reference temperature for the calibration of **telemetering** thermocouple pickups.

ZOOMAR. Variable focus lens.

Zr. Zirconium.

ZUNI. A U.S. Navy 5-inch high-velocity rocket for air-to-air and air-to-ground use, designed to replace the HVAR. It has a speed of Mach 3, weight of about 100 pounds, length of about 110 inches, diameter of 5 inches, and it is powered by a solid-propellant rocket. (See illustration facing Page 506.)

